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The European Science Notes Information Bulletin (ESNIB) is a compilation of reports on recent developments in European science of specific interest to the US R&D community, and is issued in support of the mission of the Office of Naval Research Branch Office, London. It is not intended to be part of the scientific literature. The value of the Bulletin to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. ESNIB authors are primarily ONRL staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the US Army Research, Development and Standardization Group. US scientists travelling in Europe may also be invited to submit reports.

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ESN INFORMATION BULLETIN

88-07

This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large

Commanding Officer ..... CAPT Terry J. McCloskey, USN
Scientific Director ..... James E. Andrews
Editor ..... C.J. Fox

COMPUTER SCIENCES

The author discusses the work being done by the researchers to deal with the formal specifications of real-time systems. He concludes that while a number of practical issues remain, the current efforts appear to be very promising.

CONTROL SYSTEMS

The work of the Center for Mathematics and Computer Sciences (CWI) is discussed under these topics: systems and control theory, numerical mathematics, computer science, and applied mathematics.

FLUID MECHANICS

The national Aerospace Laboratory (NLR) is the center for aerospace research in the Netherlands. It is performing work related to numerical modeling and algorithm development for a wide number of aircraft- and ship-related problems.

Important projects in the Fluid Mechanics and Heat Transfer Laboratory are wind tunnel and water channel experiments directed toward improved understanding of coherent near-wall turbulence structures. The quality of this work suggests significant contributions in the future provided the current level of funding continues.

First a comparison is made between the fluid mechanics activities at the Delft Hydraulic Laboratory and the French National Hydraulics Laboratory. Then a research program just getting underway at the Delft Hydraulics Laboratory in the area of mixing of saline-stratified flows is described. A new laser probe has been developed for use in these studies. This work is a high-priority research topic for the Dutch government and is generously funded.

The activities of the Delft University's Aerodynamics Department are reviewed. The activities specifically include those of the groups working in low-speed aerodynamics, high-speed aerodynamics, theoretical aerodynamics, aerospace design/flight mechanics, and stability and control.

INFORMATION TECHNOLOGIES

The work of PTT's Dr. Neher Laboratories (DNL), located in The Hague, is discussed. The discussion covers the activity in communications research and systems, transmission and coding, applied mathematics and signal processing, mail systems research, radio communications and electromagnetic compatibility, physics and chemistry, and applied computer sciences.

MATERIALS SCIENCE

Tribological research at TNO's research in failure mechanisms, application of lubricants, application to coatings, and friction and wear behavior of polymeric materials are covered in this article.

MATHEMATICS

Researchers at the University of Leiden are doing important work on the modeling and analysis of nonlinear diffusion-reaction processes. This article discusses the reasons for studying such problems and examines two classes of phenomena investigated at Leiden.

The Center for Mathematics and Computer Science (CWI) in Amsterdam does an excellent job of combining basic research with applications. It has recently received stimulation grants to transfer advanced mathematics to Dutch industries and government agencies. This article provides an overview of the center's work, focusing particularly on research in numerical analysis.

OCEAN SCIENCES

This report concentrates on the estuarine and coastal aspects of the work of the Hydraulics Laboratory. The author concludes that the work being done here and the support evidenced by the facilities give ample evidence of continued Dutch eminence in this field.

PHYSICS

The Department of Applied Physics at the Twente Technical University in eastern Holland is a respectable center for laser development. Noble gas halide excimer laser research is reviewed in detail; CO lasers, novel CO_2 lasers, generation of mid-IR radiation is summarized; and a brief account given of the rather new concept of electron ionization atomic lasers.

SEMICONDUCTORS

The Mega Project, a joint enterprise of Siemens and Philips, is discussed. Philips is specifically concerned with work on a 1-megabit static RAM chip, while Siemens is developing a 4-megabit RAM chip. Both chips are based on CMOS technology.

DUTCH INDUSTRIAL TECHNOLOGY IN ACTION

Foreword

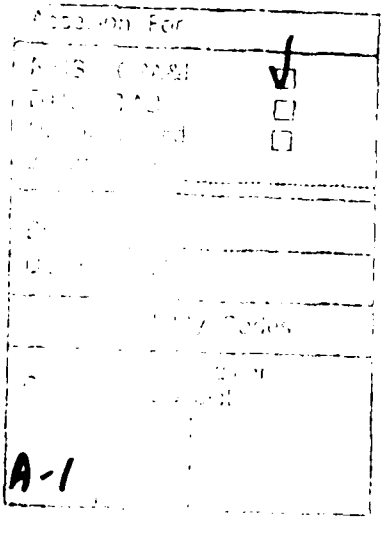
While this issue of ESNIB is devoted to science in the Netherlands, it does not presume to give a complete – or even balanced – view of Dutch science. It is instead a summary of the coverage given by contributors to European Science Notes during 1985, 86, and 87 along with articles written for ESNIB since this dedicated issue was decided upon. We have not included any material already published in 1988 because such material should be readily at hand, if not in memory, to interested readers. This issue does include information about and a perspective on Dutch technology that is due in large part to the support and assistance of the US Office of Defense Cooperation in the Netherlands and to the help of the Netherlands Naval Attaché in the UK.

While, on the one hand, the picture of Dutch science may seem to be distorted in this issue by the preponderance of articles on certain disciplines and the absence or scarcity of articles on other disciplines, we have felt that the quality of the research is just as descriptive – if not more so – of the heart of Dutch science than would be communicated by attempting to cover or comment on specific work across all disciplines.

In any case, the quality speaks for itself. These articles are the result of two primary variables: the fields of expertise of the various liaison scientists on staff at ONRL during the reporting period, and the priorities of the individuals' travel itineraries – that is, which facility visit or conference to fit in in the time available (the familiar conflict of urgencies). Also, with the focus tightly on the Netherlands itself, we have not included the ESN articles on seminars, conferences, and other international science meetings which have been held in the Netherlands, nor have we sought out the contributions – many of them of extraordinary quality – of Dutch scientists to meetings held in other countries. Regular readers of ESNIB will be familiar with such presentations and papers, at least with those in their own fields.

The lead article on R&D policy in the Netherlands provides a framework in which to view the specific technical discussion. These initiatives represent the commitment of a country approximately one-third the size but with roughly the same total population as the state of Illinois.

Taken in the context of such a small country – with sharply limited natural resources – competing for its proper share of current world trade, and, in process, securing its future economic well-being, the continued prosperity of the Dutch speaks loudly and clearly of the quality of its technology in general and of the success of its pure and applied research and technology transfer in particular. The Dutch continue to prosper and to compete with remarkable success in the areas in which they have chosen to place their scientific and technological resources. That, to use a commercial cliché, is truly the bottom line.



R&D Policy in the Netherlands

by James E. Andrews. Dr. Andrews is the Scientific Director of the Office of Naval Research's London Branch Office.

The Research Environment

The Netherlands have a long and rich tradition in fundamental science, naval matters, and the exploitation of advances in technology. As one of the smallest and most densely populated countries in Europe they have for years been involved in the challenging battle to reclaim land from the sea, in the development of efficient agricultural practices to feed the growing population, and the development of technologies to enhance the exploitation of their geographic position so that the extensive port and waterway system can offset the relative scarcity of raw materials.

Indeed, Het Nederlands Natuur en Geneeskundig Congres (NNGC), the Dutch Association for the Advancement of Science has recently celebrated its 100th anniversary. The NNGC held its first meeting in late 1887, somewhat later than other national scientific organizations, perhaps due to the strong international ties which the Netherlands have always maintained, and which have tended to emphasize the universality instead of the nationality of research. One early mission of the NNGC was to foster communications within the strongly individualistic Dutch scientific community. As this communication has grown so has the structure and organization of science in the Netherlands.

Tables I-IV (page 5) outline the structure of science and technology policy and funding organization in the Netherlands. The Netherlands have traditionally promoted science and technology as well as industrial and agricultural R&D through the support of the R&D infrastructure rather than through direct funding of specific research carried out by institutions. So-called "first flow" funds provide this direct infrastructure support through salaries and facilities, while "second flow" funds support specific programs and are used to directly impact directions in R&D. "Third flow" funds are contract funds from agencies or industry outside of the institutions' normal chain.

The Advisory Council for Science Policy (RAWB, Table II) prepares an Annual Report which is the focus of discussion for budget and policy issues at government levels. The Intermediary Agencies (Table III) are the source of "second flow" funds for all organizations.

The growth of issues on technology transfer and application have led this year to the replacement of the ZWO (the Netherlands Organization for Advancement of Pure Scientific Research), by a new body, the NWO (Netherlands Organization for Scientific Research), which is responsible for both basic and applied research. The NWO will have five or six boards for separate areas of R&D, incorporating such organizations as STW (the Technology Foundation). Dutch R&D funding for the period 1980-1988 is outlined in Figure 1. In a total 1988 national R&D expenditure of about 9 billion guilders (~$4.5 billion [1 guilder = $0.50]), the central government contributes approximately 4.1 billion guilders. Of this amount 41 percent or 1.7 billion guilders goes directly to universities in the "first flow" money. The balance (2.4 billion guilders) will be invested by NWO for technology development at the universities, research institutes (such as those of TNO), business enterprises, and international research ventures. Universities receive around 280 million guilders of this "second flow" money. Figure 2 shows the apportionment of 1988 funds on a research area basis.

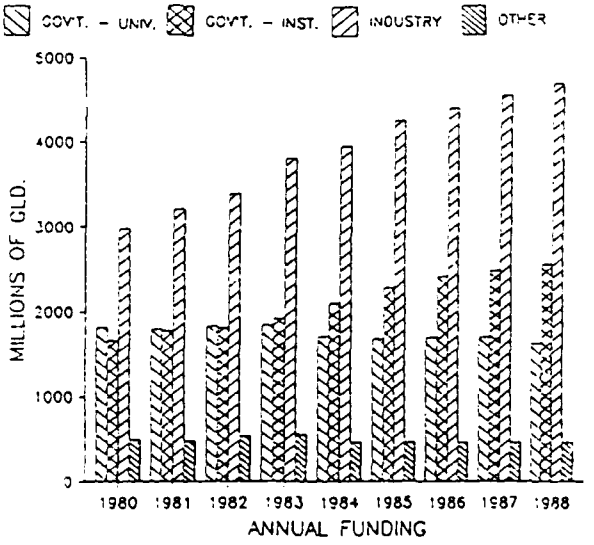


Figure 1. Netherlands annual R&D funding (1 guilder = ~$0.50).

The Organization for Applied Scientific Research (TNO) is an independent, nonprofit R&D organization with a staff of about 5000. It was established in 1930 with the aim of ensuring that applied scientific research is put at the service of the community in the most efficient manner possible. TNO's primary task is to support trade and industry in technology. TNO does this by rendering services and transferring technology, either to individual companies or to research associations. Technology is obtained from TNO's own research, through collaboration with others, or by exchanging or purchasing information.

R&D is performed in 35 branch-related or discipline-oriented institutes for, among others, the Dutch government, regional and local authorities, trade and industry, and small to medium-size enterprises in particular. The organization's working program can be roughly divided into seven main fields; defense, industrial technology, energy, the environment, nutrition and food, health, and building and infrastructure. Their Prins Maurits laboratory does innovative CW work for defense.

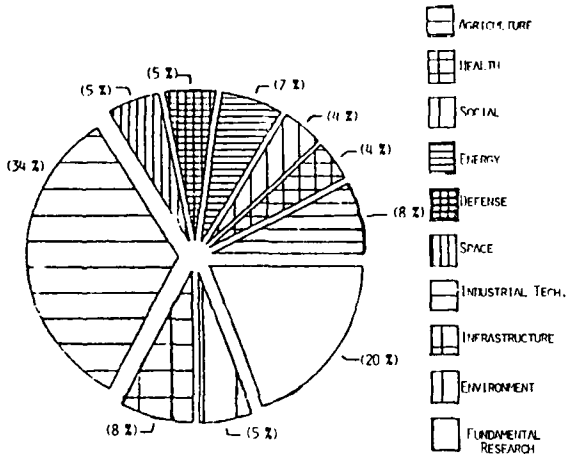


Figure 2. Netherlands government-funded R&D 1988* (*As percent of total excludes "University Research - First Flow Funds").

A trend which worries university scientists is the decrease in the "first flow" money to universities over the past few years. While small, these have been real decreases before inflation, and again reflect the swing towards technology development and transfer issues. In September 1986 the Minister for Economic Affairs (who controls the principal R&D budgets) formed the Advisory Committee on the Expansion of Technology Policy. This group, headed by Professor W. Dekker, reported in April 1987, stressing the rapid growth of the knowledge-based society and the need for rapid conversion of basic knowledge into technical applications. The committee proposed actions to increase contacts and contracts between the public and private sectors, with more R&D being carried out by small and medium-size firms. Many of the committee's thoughts were incorporated in the creation of NWO and the changes in money flow.

The Ministers' traditional advisory group, the RAWB (Science Policy Advisory Council) has responded to these proposals in its 1987 Annual Report. Normally this report addresses the coming year's budget concerns; however, in 1987 the report was issued in two parts to address both budget issues and the science and technology policies. In particular, the RAWB questions the stress of the "Dekker Committee" on commercializing the universities, pointing out that fundamental knowledge is the seed corn for future technology crops. While the Committee felt that the scientific base was sufficient and that tech-transfer was the problem, the Council felt that the resultant trimming of university budgets could only have a long-term detrimental effect. This debate will continue for some time in the Netherlands as a new science policy is forged. International programs are being stressed, along with consolidation of resources.

Research–Some Dutch Facilities and Investigations

Following are brief comments on some of the Netherlands' research and research facilitors in a number of different disciplines. This summary reflects the observations of ONRL's liaison scientists and is supplemented in the sections following by their full reports.

Fluid Dynamics/Mechanics. The National Aerospace Laboratory (NLR) is the central institute in the Netherlands for aerospace research. The articles on pages 25-29 and 33-36 discuss programs in detail. NLR has recently installed the first supercomputer in Europe, a Nippon Electric Company (NEC) 5X-2, which is rated at several billion instructions per second. NLR's principal mission is to render scientific support and technical assistance on a nonprofit basis to Dutch and foreign aerospace industries and organizations, civil and military aircraft operators, and governmental agencies concerned with aviation and spacecraft. NLR closely cooperates with the Dutch aircraft company Fokker in aircraft development projects under contract with the Netherlands Agency for Aerospace Programs (NIVR). NLR also assists aircraft operators (KLM, RNLAF) in the evaluation of aircraft and equipment, and also supports solving technical problems in Dutch aircraft industry and operations.

NLR operates four major wind tunnel facilities – the German-Dutch Wind Tunnel (Duits-Nederlandse Windtunnel-DNW), the Low Speed Wind Tunnel (LST), the Transonic Wind Tunnel (HST), and the Supersonic Wind Tunnel (SST). The DNW, a cooperative establishment of NLR and DFVLR of Germany, is the first international venture of its kind, and the largest and most versatile low-speed wind tunnel in Europe. Its outstanding aerodynamic, aeroacoustic, and logistical features allow for efficient development work on fixed and moveable wing aircraft, helicopters, and nonaeronautical projects. The laboratory carries out wind tunnel tests on a contract basis, and was used the the US Navy for tests conducted for the LHX helicopter program. The US Army aeroflight-dynamics Directorate, Moffet Field, California, is using the facility to conduct an ongoing research program of aerodynamic and acoustic testing of model rotors. This series of tests, using model rotors provided by US rotorcraft manufacturers is being performed under joint research agreements between the US Army, NASA, and major US contractors. Data from these tests will be used

in the design of the next generation of US military rotorcraft.

Electronics and Optoelectronics. The University Center for Submicron Technology at Delft Technical University carries out research in areas including VLSI, superconducting microstructures, and microsensors. Additionally, the Electrical Engineering Department is doing innovative work in large-state control theory. Using a nonlinear, mixed integer method, the researchers have pioneered work in 10,000-state, and 20,000-equation controllers for power systems modeling. The engineers at Delft are also working in robotics, and specialize in control of flexible robotic manipulators. Their control research objective is to design a robotic vision system (real-time vision recognitions/decision making) on a prototype mobile robot. The university is also investigating Artificial Intelligence techniques to automate selection of appropriate image processing algorithms. Dr. D. Collin's article, pages 33-35, provides a more detailed review of these programs.

Laser research is reported by Dr. Paul Roman on pages 51-53. The "Laser Valley" of the Netherlands is the area around Nijmegen. Much of the work is coordinated by a joint venture of universities and industries called OPTEL (Centrum voor Optoelektronische en Lasertoepassingen), which is the center for Dutch optoelectronic and laser application. The Department of Applied Physics at the Enschede (Twente) State Technical University is the leading Dutch center for lasers and laser system development. The university has built up, over the past 19 years, a well-equipped, housed, and staffed institution. The university focuses itself on high- powered gas lasers. Major current efforts are: Excimer lasers, CO lasers, CO_2 lasers, electron ionization atomic lasers, generation of mid-IR radiation and, knowledge- based CAD/CAM VLSI systems.

Marine Science. Drs. R. Brown and J. Williams in the articles on pages 32-33 and 48-50 review hydraulics and marine sciences. The Netherlands is one of the most densely populated countries on earth; 14.5 million residents live on 15,892 sq. miles. Over one-third of the land area is below sea level. Flooding of the lowlands is prevented by over 1,200 miles of dikes, dams, and dunes. Land reclamation started about 1100 AD and drainage through the intervention of pumping driven by windmills began in the early 1400's. The Barrier Dam, 20 miles long, which stretches across the mouth of the Zuiderzee was completed in 1932. It pushed the sea 53 miles northward and shortened the coastline by nearly 186 miles. The Zuiderzee ceased to exist, becoming the large fresh water reservoir now known as the Ijsselmeer. As much as 556,000 acres were reclaimed; 125,000 acres in dry land. The Netherlands Coastguard Department, in which six ministries participate (Transport, Justice, Internal Affairs, Defense, Agriculture and Fisheries, and Finance) was created in 1987 to oversee this critical resource-rich and highly trafficked zone.

The Delft Hydraulics Laboratory (DHL) is a principal laboratory in marine research and technology applications in the marine and estuarine environments. DHL carries out a variety of research missions focused on hydraulic engineering, often in cooperation with other governmental or semi-governmental organizations and universities. It is composed of : Estuaries and Seas; Water Resources and Environment; Rivers; Navigation and Structures; Harbors, Coasts, and Offshore Technology; Industrial Hydrodynamics; Hydrosurveys; and Research and Information Technology.

European Remote Sensing Satellite (ERS-1). ERS-1 will be the next satellite carrying active environmental sensors for fundamental and applied research use. The satellite is being assembled in Amsterdam by Fokker with components provided by the participating members of the European Space Agency (ESA). ERS-1 will carry a payload including of three microwave radars – a wind and wave scatterometer, a synthetic aperture radar (SAR), and a radar altimeter. These instruments are complemented by a suite of sensors including an infrared imaging radiometer and an X-band ranger. Data such as sea-surface temperature, surface wind speed and wave height, sea-surface elevation, and SAR images will be available to the scientific community. ERS-1 is ESA's first remote sensing satellite mission and since it was designed as a market opener, it is being called a pre-operational effort. Mission launch is currently scheduled for late 1989 aboard an Ariane IV launch vehicle from the Kourou Space Center in French Guiana.

Biotechnology and Biochemistry. In line with its goal of emphasizing potential practical applications TNO supports significant exploratory and applied research efforts in the area of biotechnology. On pages 18-21, Dr. C. Neurath reviews work in membrane technology, recombinant DNA research, immunology, radiation therapy, and food/nutritional research. Fundamental research within the TNO organizations supports the applied goals as well.

Behavioral Sciences. Reports by Drs. Crano and Snow on pages 7-13 review Dutch university work in fundamental and applied psychology which is aimed at education and personality functions. Understanding the educational process and introducing the rapidly evolving information technologies into the classroom both as tools and as applications for the future work place is the apparent objective. Other work in the educational field has sought to separate the variable of teaching-skill/classroom situation from that of student effort and application in the assessment of teaching practices and their impact on learning outcome. Variables ranging from class attendance, time in study, and apportioning of effort relative to class demands (i.e., exam schedules versus lec-

ture structure) are the focus in these studies. In personality-related studies at Groningen it has been shown that education – enrichment of the individual knowledge base and the discipline of the educational process – has a much stronger effect on reduction of shyness than do traditional gestalt therapeutic techniques. This finding has interesting implications beyond the immediate study in terms of other issues of social interaction.

Technology and Naval Applications

These comments on the Netherlands' technology and naval applications are, in effect, a summary of the observations and reports by ONRL's naval officers. (For more extended discussion of Dutch technology, see pages 55-59.) While being specifically addressed to naval concerns, these comments also imply the high standards of Dutch technology and of the Netherland's technical establishment to translate the fruits of research and development into new and competetive industrial, commercial, and consumer products. Certainly, the continued eminence of such companies as Philips, in electronics, and Fokker, in aircraft, exemplifies the vitality of Dutch technology.

Ship Construction. De Rotterdamsche Droogdok Maatschappij (RDM) B.V. was established in 1902 and has been constantly active in shipbuilding since that time. They have been selected by the RNLN to construct its submarines, currently a series of *Walrus* class boats. RDM is also active in the export market, offering a new generation of small (1100- to 1800-ton displacement) submarines known as the *Moray* class. The *Moray* represents a basic submarine design that is flexible to respond to varying operational needs of potential customers.

GNM/Naval Construction (van der Giessen-de-Nord) is a specially built facility for the production of glass-reinforced plastic (GRP) hulls for the series production of the Tripartite (Netherlands, Belgium, and France) Mine Countermeasures Vessels (MCMV). The Royal Netherlands Navy has ordered 15 of these vessels. The production process and the GRP construction methods vary considerably from those of the Italian company, Intermarine, which produces the *Lerici* class MCMV. GNM uses a plate-stiffener construction vice the monocoque approach of Intermarine. At GNM the ships are constructed in a production line process where the hulls move from station to station to accommodate the work force and equipment. The line has four stations, the first two essentially for GRP production and the last two for fitting out. There is a fifth station for final testing.

Machinery and Propulsion Equipment. Van Rietschoten and Houwens B.V. (R&H) has specialized in designing, supplying, and installing machinery, equipment, and complete systems on board naval ships since 1860. Headquartered in Rotterdam, R&H is a world leader in the areas of electronic and computer engineering and systems. Of particular interest is the Rudder Roll Stabilization systems (RRS) which they have developed for the RNLN's *M* class frigate program. RRS is an adaptive control system combining the functions of a modern autopilot and a roll stabilization system using the rudder as the only actuator. It is claimed that the RRS offers the advantages of reduced drag and less radiated noise over conventional fin-stabilization systems. The US Coast Guard has tested the RRS on one of its ships.

Promac B.V. designs and manufactures a modular desalination system based upon the reverse osmosis principle. Their applications include both a naval version and a mobile drinking unit for use ashore.

Schottel Nederland B.V. is an independently run subsidiary of Schottel of Germany. They have more than 25 years' experience in the construction of main propulsion systems and maneuvering aids. They offer more than 20 different types of rudder-propellers covering a power range from 15 kW to 4500 kW. These types include Schottel navigators, transverse tunnel thrusters, bow-jets, cone-jets, and pump-jets. Schottel also manufactures the antimagnetic, low-noise, shock-resistant bow thrusters for the Tripartite MCMV program.

Electronics and Related Equipment. Hollandse Signaalapparaten (Signaal) is a leading company in the field of defense electronics with, in the naval sector, an across-the-board range of products including sensors, telecommunications equipment, combat information, and weapon control systems. The company belongs to the Philips group of companies, and is one of the 12 companies within the Defense and Control Systems Division.

Draka Kabel B.V. specializes in the manufacture of electrical wire and cable for voltages up to 35 kV. The R&D activities of Draka have included the study of the electrical, physical and chemical properties of its product range. They have developed a number of cables especially for naval applications, including halogen-free cables, fire resistant cables, and buoyant cables.

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Table 1. The government science and technology structure.

PARLIAMENT:	
Standing committees on	Science Policy University Education Economic Affairs
GOVERNMENT:	
Council of Ministers	
Council for Science and Technology Policy (RWT)	Council for Information Policy
Inter-Departmental Commission for Science Policy (IOW)	Inter-Departmental Commission for Information Policy
Inter-Departmental Commission for Technology Policy (IOT)	
Ministries	Education and Science Economic Affairs Agriculture and Fisheries Housing, Town and Country Planning Environment Foreign Affairs Welfare, Health, Culture

Table 2. Advisory bodies.

Advisory Council for Science Policy (RAWB)
Royal Academy of Arts and Science (KNAW)
Advisory Council for Higher Education (ARHO)
Scientific Sector Councils:
- National Council for Agricultural Research (NRLO)
- Council for Environment and Nature Research (RMNO)
- Council for Health Research
- Advisory Council for Scientific Research in the Framework of Development Cooperation (RAWOO)
- Programing Forum for Town and Country Research (PRO)

Ad Hoc Exploration Committees (e.g., physics, chemistry, biology)
Programing Committees (e.g., criminal research, welfare research)

Table 3. Intermediary agencies.

Netherland Organization for Scientific Research (NWO)
Technical Sciences Foundation (STW)
Foundation for Coordination of Maritime Research (SCMO)
Steering Committee for Innovation-oriented Research Programs (IOPS)
Netherlands Agency for aerospace Programs (NIVR)
Stimulation Project Team for Information Technology Research (SPIN)
Applied Research for Roads and Waterways

Table 4. R&D performing organizations.

R&D Institutions:	FY85 (million guilders *)	Staff
Universities and Technical Universities	560	4,700
Organization for Applied Scientific Research (TNO)	1,800	15,000
Large Technical Institutions:		
Netherlands Energy Research Foundation (ECN)	90	800
Delft Soil Mechanics Laboratory (LGM)	30	250
Netherlands Maritime Research Institute (MARIN)	40	400
Hydraulics Laboratory (WL)	65	600
National Aerospace Laboratory (NLR)	100	700
Other Institutions:		
Agricultural Institutes	240	2,500
KNAW Institutes	45	500
NWO Institutes	115	800
State Institute for Health Care and Environment Protection (RIVM)	100	1,300

***1 guilder = $0.50**

Table 5. Universities and Research Institutes.

Institution	Enrollment (1984)	Sci. Staff (FTE)	Non-Sci. (FTE)
Leiden State University	17868	1634	1486
Groningen State University	17049	1741	1580
Utrecht State University	22623	2294	2254
Rotterdam State University	12329	1027	877
Limburg State University	2300	504	508
Amsterdam (Municipal) University	24384	2196	1610
Amsterdam Free University	12540	1405	1153
Nijmegen Catholic University	15069	1517	1358
Tilburg Catholic Technical University	6406	446	308
Delft State Technical University	11556	1412	2328
Eindhoven State Technical University	5606	777	1155
Enschede State Technical University	4367	636	906
Wageningen State Agriculture University	6780	754	1233
Interuniversity Research Institutes (12)		435	
KNAW Research Institutes (13)		514	
NWO Research Institutes (27)		1090	

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BEHAVIORAL SCIENCES

University Curriculum Structure and Student Working Behavior in the Netherlands

by Richard E. Snow. (This article was originally published in January 1985 [ESN 39-1]). Dr. Snow was the Liaison Scientist for Psychology in Europe and the Middle East for the Ofice of Naval Research's London Branch Office from September 1983 through September 1985.

Much research in educational psychology has sought to link variations in teaching practices and materials to variations in learning outcomes. But the teaching-learning relationship is not direct; it is mediated by the amount of effortful work students actually invest in learning, and effort in turn may be influenced by a host of other personal and situational variables. Since these intervening and moderating variables are difficult to identify and measure, clear evidence useful for the improvement of instruction is often difficult to come by.

In recent years, some research attention has turned to the study of student working behavior expressed as time-on-task. Using time as a variable also has its problems. It is an imperfect, surrogate index for the underlying psychology it is taken to reflect; one cannot assume that time spent equals mental effort invested or that comparisons of time within or across persons reflect comparisons of learning processes. On the other hand, time measures offer advantageous mathematical properties and direct practical interpretation, so they deserve serious study. Most of the research on time-on-task has relied on observations in US public school classrooms. Another approach, using self-report time logs, has recently been used to advantage in a continuing series of studies of Dutch university students. Students keep their own confidential logs, turning the records in periodically to the researchers in exchange for a promise of anonymity with respect to faculty members.

Crombag (1984) provides a summary discussion of the work to date. Detailed accounts of the individual studies are available in the technical report series of the Educational Research Center, University of Leiden, The Netherlands, and from Ten Cate (1984), Van Os and Brants (1982), and Vermeer (1977) for some other Dutch universities.

Traditional Dutch university courses consist of a series of lecture classes spread across 10 to 13 weeks, followed by a period of several weeks devoted to examinations. Figure 1 shows the average amount of time spent per week in class and in independent study outside of class by students in an introductory physics course for second-term chemistry freshmen. Figure 2 shows the same course plus three other concurrent lecture courses in the second-term chemistry curriculum; each curve here gives the average total class-time plus independent study time for each course.

Figure 1. Class attendance time (solid) and independent tudy time (dotted) in an introductory physics course for chemistry freshman (from Crombag, 1984).

This trend is clear; students spend very little time studying as the lectures proceed, preferring to cram for each exam in turn during the period between the last lecture and the exam. Many courses – across the fields of biology, chemistry, dentistry, languages, law, medicine, and psychology, and across four universities – show much the same pattern. Thus, although the instructor plans each lecture to build on previous learning, students on average ignore this plan; the pattern clearly suggests distributed teaching over the course but massed learning only at its end.

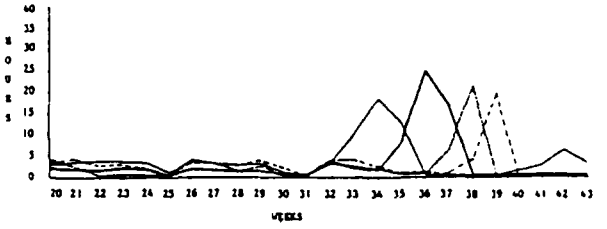

Figure 2. Study load during second term of chemistry curriculum for four courses (from Crombag, 1984).

Some courses will yield a different pattern if they are organized to require intermediate student products during the course. Figure 3, for example, shows class attendance and independent study averages in a laboratory course for chemistry freshmen that required periodic written reports from students.

There is also competition for time across courses, and small changes in curriculum organization sometimes can affect appreciably the distribution of student working behavior. As one example, Crombag (1984) cites the data shown in Table 1 for the two largest courses in the first-year law curriculum. Between the two data years shown, the only change in curriculum structure was to reverse the order of the exams for the two courses and to allow more time between them; in 1979-80, the exam for the general introductory course came first with 1 week between exams, whereas in 1981-82 the criminal law exam came first with 2 weeks between. The change produced a marked increase in time spent on criminal law and in the percent of students passing the exam, with a slight decrease in time spent on the introductory course but no decrease in the percent of students passing. The conclusion that the organization of the curriculum, both within and across courses in a department, is a major determinant of student working behavior is supported by a variety of other analyses. These include studies of detailed hourly time logs over the days of several weeks as well as weekly study logs alone. Crombag and his colleagues argue that what we typically think of as individual student motivation may be much less important than curriculum structure as an influence on student work. Evidence on this point, however, would require analyses of individual differences in independent study time and also the approaches to learning applied by different students in this time. The Crombag research at least makes the important point that the time implications of different curriculum structures cannot be ignored in studies of student motivation for study.

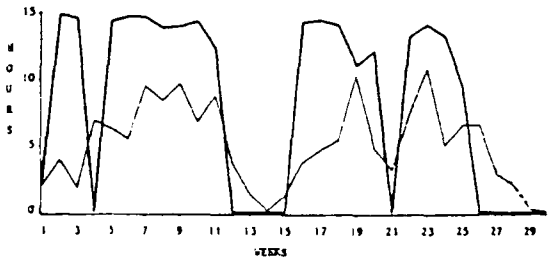

Figure 3. Class attendance time (solid) and independent study time (dotted in a lab course for chemistry freshmen (from Crombag, 1984).

The Dutch research speaks to a related and also important point. The relationship between class attendance and independent study might be hypothesized to be positive. However, as the total time load for a curriculum increases, competition for time between class attendance and independent study also increases; the relationship between class time and amount of independent study time per class should thus be negative in some range. Precise understanding of this complex relationship could suggest optimization rules for allocating expensive class hours to produce maximal independent study.

Table 1. Student Work Patterns and Pass Rates for Two Law Courses in Each of Two Years.

Course	Year	Total Hours Assigned	Total Hours Realized	% Hours Realized	% Passing Exam
Gen.Intro. to Law	1979/80	275	228	83	56
	1981/82	275	198	72	60
Criminal Law	1979/80	325	159	49	64
	1981/82	325	234	72	78

Crombag and his colleagues constructed the negative exponential curve shown in Figure 4 based on data from six first- and second-year curricula in four different Dutch universities. The two points (number 7 and 8) from two additional first-year curriculum areas conform well to the same curve. In each instance, the data reflect only the behavior of students who passed their examinations, aggregated over the whole year. Thus in this range the amount of independent study per hour of class attendance de-

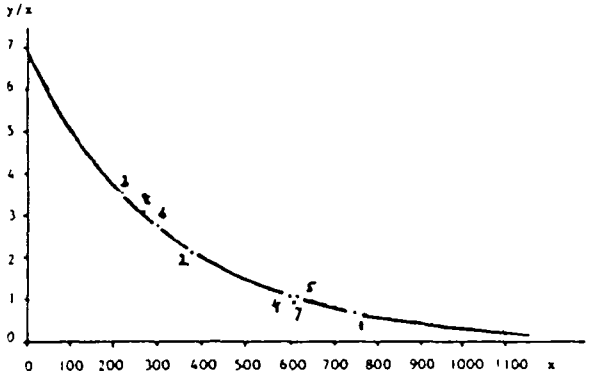

Figure 4. Relationship between class attendance (x) and amount of independent study per hour of class (y/x) (from Crombag, 1984).

creases as the amount of class attendance increases. A simple transformation of this function to express directly the relation between average class attendance and average amount of independent study yields the optimization curve of Figure 5. This suggests that an average of 325 hours allocated to class time should elicit the maximum of 820 hours of independent study, on average. More or less class time yields less independent study. One could imagine curriculum changes, however, that might drive independent study time up without adding appreciably to class hours. But these changes lie outside the range of Dutch curriculum structures producing the present curves. From other sources, Crombag estimates that students would need to realize 1300 net hours of work per year to equal the work rate of the average employee in Dutch industry. To achieve this, within the present for-

mulation, class attendance would have to exceed 1000 hours per year, which is quite unrealistic.

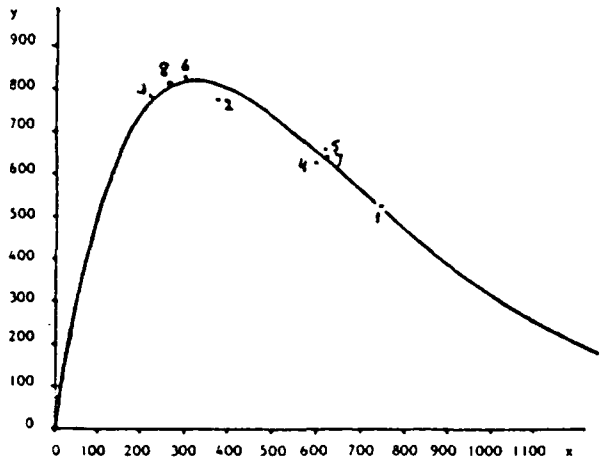

Figure 5. Relationship between average class attendance (x) cand average amount of independent study (y) (from Crombag, 1984).

Finally, Crombag (1984) notes that in the US, and in some other countries, it is claimed that university student work averages substantially exceed 1300 net hours per year. He calls for cross-national comparisons on this point and offers the curves shown in Figure 4 and 5 as baselines for such research.

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January 1985

Educational Sciences and Technology A New Specialization in the Netherlands

by Richard E. Snow. (This article was originally published in June 1985 [ESN 39-6].)

The rapid growth of new information technologies (NIT) is creating short-term and long-term demands on the educational systems of most industrialized nations. In turn, a critical concern is the adaptation of education to NIT, both to meet national needs for NIT specialists and to use NIT to improve education across the board. A previous article (*ESN* 39-5:179-183 [1985]) described some of the policy issues identified through surveys of the problem in France, Sweden, and West Germany. The present article reports on relevant Dutch initiative.

In brief, three issues stand out at the intersection of NIT, education, and industrial training needs:

1. How to use NIT to improve school-based education at all levels and to increase computer literacy in the student population generally.

2. How to improve education, particularly in the sciences, mathematics, and technologies needed as preparation for advanced training in NIT specialities.

3. How to improve industry-based training in NIT-related fields and its links with the school-based educational system.

Underlying all these issues is the need to harness what has been and can be learned from research in psychology, education, and related social sciences to the task of instructional improvement.

Twente University of Technology in Enschede, the Netherlands, and its innovative new department of Educational sciences and Technology is at the center of the Dutch attack on these issues and needs. Twente was founded in 1962 as the third Dutch technical university (the two older institutions are in Delft and Eindhoven). Its primary emphasis has been in mechanical, chemical, and electrotechnical engineering, physics, and mathematics; students could also choose an extra concentration in business administration. In the 1970's, the government decided to add two applied social science emphasis that would be closely allied with the science and technology strengths already present. One was public administration; the other was education, opened to students in 1981.

It is important to note the features that make this undertaking unique. Although there are interdisciplinary educational science programs in many of the older Dutch universities, they are 2-year postsecondary courses for students, and they represent fairly traditional mixtures of psychology, education, and related social sciences; faculty research in these departments addresses important, but mostly traditional, educational problems. In Twente, the academic program in educational sciences and technology is designed expressly for students with strong pre-university training in science and mathematics; it requires

4 years of study leading to the Dutch equivalent of a US master's degree. The aim is to educate students for careers in which the solving of complex problems within educational practice is central.

The essentials of behavioral and social science knowledge and methodology are included, but the major emphasis is on the use of this source to improve educational technolgy, especially the use of NIT in instruction. Instructional design and development, educational measurement, and evaluation are the foci. There is close cooperation with the Center for Education Information Technology in the same building; this center is a national advisory body to public schools on the use of computers in education. There is also close cooperation with the Center for Educational Research and Development, an arm of the Twente University Science and Technology Departments, that specializes in instructional designs for the improvement of problem solving in science education at the university level. There is also much interaction with government and industry as clients; students spend a significant part of their time working on instructional design and organization problems in various major electronics, manufacturing, banking, and retail sales firms, as well as several government agencies. The aim of this present work is to promote theory-practice and university-industry linkages. The course sequences are modularized, mastery-oriented, and largely self-paced. Detailed description of the educational program is provided by Plomp and Verhagen (1982, 1983).

Unlike most educational technology departments in the US, which have evolved in traditional colleges of education, the Twente program was established without precedents. Its view of educational problem solving is much more akin to the view of systematic analysis and scientific problem solving found in the physical sciences and engineering fields. Its approach and its goals, therefore, approximate more closely the ideal picture of a "design science" envisioned by Simon (1969) and Glaser (1977) than do most of the educational technology programs in the US. It will be important, as the Twente program continues to develop, to evaluate its impact on the major NIT-related problems in the Netherlands.

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Research in Personality at the Rijksuniversiteit Groningen

by William Crano. (This article was originally published in March 1987 [ESN 41-3].) Dr. Crano was the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office from June 1986 to August 1988.

The scientific contributions of the subdepartment for personality psychology at the Rijksuniversiteit of Groningen give lie to the minuscule size of its faculty. The group not only is active, but their activities cover a wide range of some of the most interesting phenomena in the field of personality. This report details some of the work on personality currently being undertaken in this small university city in Holland's north country.

From Soup to Nuts

An intriguing feature of the Groningen group is the easy coexistence of both basic and applied personality researchers. Although the group contains no psychologists doing actual clinical work, some of the activities of the faculty have, at a minimum, a decided "counselling" flavor. Yet, interactions between the basic researchers and the practitioners within the group are cordial, and the work

of each psychologist appears to reinforce that of the others.

At the applied end of the Groningen personality research continuum, Gerrit Lang has undertaken a programmatic approach to the communal treatment of shyness. His method, which is marked by almost constant evaluation and reevaluation of the various components of the treatment, appears to have a very positive influence on the lives of those exposed to it. At the more basic pole, Jos ten Berge's psychometric work on the reliability of instruments serves as the foundation for much of the work of all of the subdepartment's members, who make extensive use of questionnaires in the assessment of subject-clients (in Lang's case) or the evaluation of their laboratory and field-experimental manipulations (as in the work of Liebrand and Hofstee).

Intermediate to the studies of Lang and ten Berge is the work of Wim Lebrand, and of Willem Hofstee (who also heads the subdepartment). Lebrand has been interested in the role of individual differences in behavior in complex social dilemmas, while Hofstee has been involved in a wide range of research issues in personality, including the study of creativity, the development of new models of evaluation, the measurement and taxonomy of personality traits, and the construction of psychometric models for analysis of personality questionnaires.

My review does not detail all of the many facets of research that can be observed in operation in this group – indeed, discussion of Liebrand's very interesting work will be held for a future edition of these notes, when a more complete discussion of social dilemma research in Europe is presented. Rather, this review is intended to provide a flavor of the work in the subdepartment, and to give an indication of some of the more interesting developments issuing from our colleagues in the Rijksuniversiteit Groningen.

The Prison of Shyness

For those trapped within themselves, shyness is indeed, as Zimbardo is said to have observed, "like a prison." Lang and his colleague Henk van der Molen have set up a university course that is designed to alleviate the major difficulties associated with this multifaceted problem. The course is based on an educational, rather than psychotherapeutic, model. Lang holds that an educational model (treatment as education) emphasizes the personal responsibility of the sufferer in overcoming his problem. In developing their approach, Lang and van der Molen began with three broad project aims:

- Develop a number of short, educational programs with clearly formulated aims, to deal with shyness.
- Implement these programs in classroom settings. This reflects the communal nature of the treatment approach, and also a rejection of the term "therapy," which the authors have found to have a negative, stigmatizing, influence which works in opposition to a program aimed at the amelioration of shyness.
- Evaluate their effect. This last aim is characteristic of the approach, which is constantly refined by data-based feedback. The emphasis on evaluation was undoubtedly a major factor in the success of the program, and reflects a general characteristic of all of the work of the subfaculty.

A person is considered shy if in social situations he habitually must deal with feelings of tension, a lack of knowledge regarding proper behavior, and a negative, self-deprecating conception of the self. In an impressive field experiment, van der Molen randomly assigned subjects – who had volunteered for the course in response to newspaper advertisements – to one of two treatment conditions, the first of which was based on the idea that knowledge and an enriched repertoire of behavioral dispositions, combined with a decrease of irrational thought patterns (through lessons, social skills training, etc.) would lead to a reduction of tension, greater self-confidence, and more positive social experiences. A parallel treatment condition was based more on Gestalt theory, which focused on a deepening of self-insight via awareness exercises and Gestalt therapeutic techniques.

A pretest-posttest design with repeated and follow-up measures (assessing both self-perceptions and behavior) revealed that while both methods were effective, the educational approach was superior to that of the Gestalt-based model at the initial measurement period, and this superiority was even more pronounced over time. Modified versions of the Lang approach have been employed in various subject populations – students, married couples, nursing students, etc. – and the general results described here have been replicated. A detailed description of early work may be found in the book by H. T. van der Molen (1985). It is important to realize that this work has potential implications not only for shyness, but for other social difficulties as well. If an educational (vs. therapeutic) approach can help painfully shy people become more outgoing, perhaps a similar approach can be used to treat other interpersonal difficulties that have a negative influence on people's abilities to relate to others, to form useful and productive working arrangements, etc.

A Potential Difficulty. The fact that students self-select themselves into Lang's program is a cause of some concern. The potential problem, of course, is that of self-selection bias. Obviously, a pathologically shy person might never have the courage to enroll in a program that could be of some help in combating his or her difficulty. Lang is aware of this problem. Although unable to assign subjects at random from the population to his classes, he has attempted to gauge the severity of the shyness problem of those who do enroll. The student-clients in his treatment sessions are far from gregarious, outgoing, extroverts. Lang evaluates the severity of his subjects' shy-

ness problems as comparable to that of outpatients in psychiatric hospitals – not completely debilitating, but certainly extremely bothersome. So, at a minimum, Lang's treatment appears effective in populations of extremely, if not pathologically, shy people.

Reliability of Scales

Much of the work of Lang and of the other researchers in the subdepartment is based on people's responses to personality questionnaires. Consequently, it is natural that extracting the maximum reliable and valid information from such measures is paramount. Hofstee and ten Berge have studied various facets of this issue intensively, and the results of their research deserve mention.

Lower Bound. Jos ten Berge's work in this area has been focused on the derivation of the lower bound of the (internal consistency) reliability coefficient. He notes correctly that Cronbach's alpha (α, in classical test theory) is the most popular lower bound to scale or test reliability. Guttman derived a similar statistic with his $\lambda 2$, which is always at least as good a lower bound as alpha. A consideration of the computational formulae for these two statistics will show why:

$$\alpha = \frac{n}{n-1} \cdot \frac{\Sigma \sigma_{ij}}{\sigma_x^2}$$

and

$$\lambda 2 = \frac{\Sigma \sigma_{ij} + \left\{ \frac{n}{n-1} \cdot \Sigma \sigma_{ij}^2 \right\} \cdot 5}{\sigma_x^2}$$

where σij is the covariance between items i and j, σ^2 is the variance of the total test, and n is the number of items. The superiority of $\lambda 2$ is attributable to the fact that it uses the *sum of squares* of the covariances between items in addition to the sum of these covariances. Ten Berge has shown that $\lambda 2$ can be improved upon by using the sum of the fourth powers of item covariances, the fifth powers, and so on. Practically speaking, the second power is generally sufficient. Beyond this, the computational efforts involved are not worth the minuscule gains realized in the reliability coefficient. Although this approach is relatively unappreciated by most scale constructors, it is very useful in situations involving instruments of relatively few items which have a wide spread of absolute values of covariances between items.

Moderator Effects. In a personality questionnaire, the data to be analyzed consist of subjects' endorsements of the available response options over a group of items. The analyst's task is to determine a means of combining responses so that the resulting score is either maximally valid in predicting some criterion, or maximally reliable (i.e., internally consistent). Most commonly, a simple unweighted item-summation approach is employed in scoring such instruments, although at times items are weighted by their item-total correlation, or by their factor loading, in arriving at a weighted sum. Generally, the nonunit weighting approaches do not appreciably enhance reliability.

Conceptually parallel methods are used in attempts to enhance predictive or criterion validity through what might be called the internal manipulation of scale responses. One approach to the enhancement of the validity coefficient that on the surface appears quite useful calls for the systematic search for moderator or suppressor variables in the measurement instrument. Is there a way, in other words, to combine or recombine scale data in such a way that validity is maximized. This is not a new idea – suppressor models were employed in early research on response sets in the F scale (see Adorno et al., 1950). Review of this literature provides little evidence for the utility of the suppressor orientation (see Campbell et al., 1967; Crano and Brewer, 1986; Rorer, 1965); however, it is conceivable that this failure was issue specific. Perhaps with issues that are not so fraught with social/political controversy, suppressor effects might be more in evidence. Or, it might be that with a more refined methodological-statistical conceptualization, the moderator or suppressor approach might have positive implications for validity. It is to these possibilities that Hofstee directed his attention.

Moderator effects can be defined precisely by the classic moderated regression equation,

$$Y = a + bX_1 + cX_2 + dX_1X_2$$

where
Y is the predicted criterion,
X_1 and X_2 are predictor variables, and
a, b, c, and d are regression weights.

Moderator effects are indicated when the weight of X_1X_2 in predicting the criterion is nonzero. This general conceptualization of moderator effects was applied by Hofstee in a test of a proposal by Jackson. To increase predictive validity of personality scales, Jackson suggested that two additional variables be developed: a salience parameter, which reflects a person's sensitivity to the underlying dimension tapped by the scale items, and a threshold parameter, which indicates the person's standing on the dimension. The salience and threshold parameters are the slope and intercept of the regression of the individual subject's item responses on the dimension of interest. The moderator model is appropriate in this instance since the salience parameter represents the relevance of a scale for a subject.

Using two major (Dutch) data sets, Hofstee tested whether the addition of these two parameters to the total score increased the criterion validity of the scales. The data sets he used were the Standard List of Personality-Descriptive Adjectives (SPEL; Hofstee et al., 1981), and the Dutch Personality Inventory (DPI; Luteijn, 1974).

Scale identification and relevant test characteristics of the subscales of these instruments are presented in Table 1.

Table 1. Scale Labels and Item Statistics for the SPEL and DPI.

SPEL Subscale	# Items	Alpha	Validity[a]
Culture	24	.79	.17
Emotional Stability	26	.79	.63
Agreeableness	22	.75	.18
Irritability	21	.77	.23
Conscientiousness	19	.77	.60
Introversion	17	.69	.18
Conservatism	6	.75	.51
DPI Subscale	**# Items**	**Alpha**	**Validities[b]**
Inadequacy	21	.86	-.12 .10 .16
Social Inadequacy	15	.83	-.10 .06 .14
Rigidity	25	.77	-.16 .16 .14
Injustice	19	.77	-.16 .24 .08
Self-sufficiency	16	.68	-.11 .11 .03
Dominane	17	.72	.07 .02 -.12
Vigor	19	.68	.06 -.04 -.14

a – Zero-order validity against peer rating.
b – Zero-order validities against psychiatric rating on Stability, Neuroticism, and Anxiety.

SPEL had been administered to 200 respondents; a close acquaintance of each respondent who completed the scale provided criterion validity information. For the DPI, validity information was provided by psychiatric ratings of the stability, neuroticism, and anxiety of each of the 464 respondents. For each subject in both test administrations, Hofstee calculated over all subscales the unweighted sum score, the intercept of the linear regression of the items, and the slopes (again, for each subscale). He used each of these variables in a stepwise regression analysis to predict the criterion scores for each subscale. Seven such analyses were undertaken for the SPEL data (since there were seven subscales), and 21 for the DPI data, since three psychiatric ratings were available for each of the seven subscales.

In none of the 28 analyses did the addition of the moderator variables result in an improvement (at $p < .01$) in the regression of criterion on unweighted sum scores, and in only five of the 28 analyses did the difference between the multiple correlation and the simple sum-criterion correlation reach the standard ($p < .05$) level of statistical significance. The addition of yet another moderator term in the prediction equation, the square of the slope parameter, b^2, did not improve matters.

Although it is difficult to dismiss an hypothesis on the basis of a null result, an entire table full of null findings does provide grounds for speculation. On the basis of his findings, Hofstee has observed that it is unlikely that the simple within-scale manipulation of data through more sophisticated scoring approaches will result in incremental validity. Indeed, it is clear that Hofstee would agree that the farther the investigator shifts the data from the original (be they pencil marks on a page, simple reaction times, or recall scores), the greater the danger of introducing unwanted error or bias into the results. In the first instance we conclude with less than is there, and in the latter with more than we should.

Hofstee's injunction to submit all novel scoring approaches to a psychometrician, who is to try to tear it apart, and then only to use the technique after the methodologist has given up, seems a reasonable and reasoned approach to the invention of methods that attempt to squeeze more from questionnaire responses than the responses indicate on the surface. Such an approach recognizes the fallibility of our data, and provides a more sure means of attenuating the "fallibility coefficient."

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12/2/86

BIOLOGICAL SCIENCES

Dutch Military Lab Surveys RF-Generating Equipment

by Thomas C. Rozzell. (This article was originally published in March 1985 [ESN S39-3].) Dr. Rozzell was the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office from August 1983 to August 1985.

The Laboratory of Electronic Developments for the Armed Forces in the Netherlands recently conducted a survey of the radio-frequency (RF) generating equipment in the country. The survey was commissioned by the Ministry of Health and Environmental Hygiene and included most of the civil RF sources in the frequency band from 0.5 MHz to 18 GHz. In addition to doing an inventory of the range of transmitters, the project had as its objective the development of a computer model that will be capable of predicting the RF environment from a knowledge of certain of the parameters of the transmitter.

In a recent visit to the laboratory, an institute of the Netherlands Organization for Applied Scientific Research (TNO), I learned that this project was carried out by a military institute for a civilian agency because no agency within the civilian part of the government has the expertise needed for such a survey. It was interesting that no consideration was given to military sources of RF energy. There is no legal standard in the Netherlands for human exposure to electromagnetic energy, although the American National Standards Institute standard is highly regarded and generally followed by anyone wishing to use some sort of guideline. The military, however, seems a bit isolated from such considerations, and apparently no guidelines are actually followed by military operators – except for keeping exposures as low as possible. This probably works quite well given the size and complexity of the military force in the Netherlands.

Approach to Study

The project team did not set out to survey every installation that had RF-generating equipment as this would have been impossible in the time allotted. Instead, a representative sampling was made and, using literature sources about industries, the team was able to extrapolate data for the whole of the Netherlands. Several classes of generators were evaluated in the laboratory as well as being measured on location and in actual use. Three types of medical diathermy equipment were studied: shortwave (27.12 MHz), UHF (433.92 MHz), and microwave (2450 MHz). RF heaters and sealers – such as those used for sealing plastic materials, gluing wood, and drying potato chips – were evaluated at inplant locations.

The computer program developed under the project was designed so that it will roughly predict the RF-environment around different types of emitters using the transmitter parameters. The first task was to decide which parameters should be sought. The ones chosen are listed in Table 1. These parameters were considered easy to obtain from operators of the equipment and from public records. However, it was realized that in some cases, these parameters might not be very accurate. It was often difficult to obtain the needed information from public documents or from owners and operators of transmitting devices. In some cases it was necessary to seek the information from the manufacturer or to estimate it. This task was more labor intensive than was originally thought, and to date, parameters have been fully obtained for only 150 sources of RF energy.

Table 1. List of Parameters

I General	II Antenna	III Transmitter
1. name	11.type	32. power
2. application	12. illumination	33. frequency band
3. info source	13. dimensions	34. p.r.f.
4. location	14. beamwidth	35. duty cycle
|	|	|
|	|	|
|	|	|
|	|	|
10. – – – – –	31. – – – – –	39.. – – – –

Different approaches are used to calculate the power flux density (PFD), depending on the completeness of the input data. For instance, if the illumination of an aperture antenna is unknown, the program uses other parameters to estimate the illumination (such as the dimensions of the aperture and the beamwidth). In addition, the program can manipulate data, such as updating the data bank and ranking the transmitters. Finally, it can plot different graphical presentations such as:

- PFD as a function of distance of one transmitter
- Maximum PFD as a function of frequency of a selected subset of transmitters
- Geographical view of transmitter locations
- Some form of statistical information, such as the number of transmitters and the distances at which their PFD's exceed a definite value.

Study Results

A crucial part of the survey was the measurement of actual fields that existed in the environment around sev-

eral types of equipment. These measurements were done in industries using RF energy for such tasks as sealing plastics, and in medical situations for which diathermy is used. This was the beginning of data collection to verify the computer model. Three different types of sealing machines were measured at two different plants. Field intensities were measured in the vicinity of the operator positioned in the normal operating position.

Figure 1 shows the results obtained for all of the sealing machines measured. It is interesting to note that approximately 14 percent of all values are higher than 10 mW/cm^2, and roughly 56 percent are higher than 1 Mw/cm^2. Some types of machines are worse than others, with the turntable machine giving, for example, 78 percent of the measurements in its vicinity above 1 mW/cm^2.

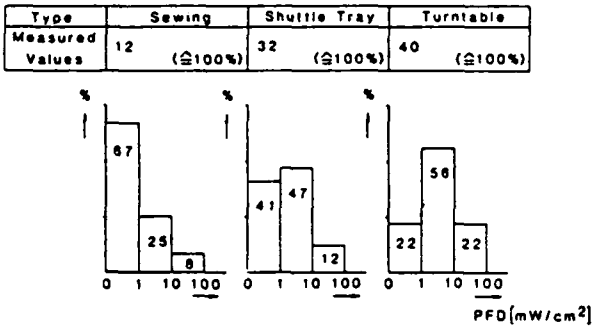

Figure 1. Exposure results for sealing machines.

(All values were corrected for duty cycle, i.e., the sum of the time period when the power is "on" and "off.") When the extreme exposure levels were examined, it was found that this was about the same of all three types of machines (around 30 mW/cm^2), but the part of the body exposed at the maximum level was different. In the case of the "sewing" type, the knees received the maximum, while it was the head for the "shuttle tray" machines and the waist for the "turntable" type (Figure 2).

Sealer type	No. units	Exposure level (mW/cm^2) min	max	Part of body max. exposed
Sewing	3	<0.2	26.4	Knees
Shuttle Tray	5	0.2	30	Head
Turn-table	5	0.2	29.7	Waist

Figure 2. Exposure levels by type of machine.

Although the sample size was too small to draw conclusions concerning all types of sealers, the project team did draw some general conclusions:

- The exposure levels are fairly high.
- Peak levels are two to 10 times higher depending on the duty cycle; the maximum peak level found was 300 mW/cm^2.
- Levels can be reduced by shielding; a shielding effectiveness of more than 20 dB was measured.

Measurements of medical diathermy units were carried out in two parts. First, measurements were made of some units in the laboratory using a probe mounted on a mechanical positioner that could be moved in all three directions in front of the diathermy unity. A series of scans was thus made in the X-Z plane at different distances Y from the applicator. From these scans it was possible to get an impression of the spatial distribution of the PFD around the diathermy applicator. This is, of course, without benefit of a patient in place.

To obtain a reasonable picture of the RF levels to which operators of diathermy machines might be exposed, the team went to four different training centers where physiotherapists were trained in the use of the devices. During treatment sessions the team measured the PFD at a number of positions close to the units and close to the patients. Normally, the power setting used was one that produced a slight sensation of heat in the patient.

Although the PFD levels were at the position of the treated body parts, it was found that all values in positions where the operator might be – or at untreated parts of the patient's body – were generally less than 10mW/cm^2.

Concluding Remarks

This type of survey and computer modeling project is unique in that it was carried out by a military laboratory for a civilian agency. It is also the first time, to my knowledge, that an attempt has been made to develop a computer program that can predict PFD around an RF radiator used in industrial and medical environments. Surveys have been made on board ships and around commercial broadcasting antennas by various groups in the US and other countries. An approach like that used by the TNO group might have applications to the problem of predicting levels of exposure to US Navy personnel on the decks of ships, particularly in the multifrequency environment, where it is often difficult to integrate the PFD due to transmitters operating at several different frequencies.

March 1985

Bone Replacement and Drug Delivery at the Free University of Amsterdam

by Thomas C. Rozzell. (This article was originally published in June 1985 [ESN 39-6].)

Traumatic injury caused by projectiles or by a number of routine activities of military personnel must often be treated by replacement of bone tissue. Over the years, surgeons have used a number of synthetic materials in addition to autologous, homologous, or heterologous bone. Materials that have been used for such biomaterials include metals, alloys, glasses, ceramics, carbons, polymers, and a host of composites of these and other substances. The search for an ideal bone-substitute material is one of the primary activities of the Biomaterials Department in the School of Dentistry at the Free University of Amsterdam. This group, led by Professor Dr. K. de Groot, is also involved in research on the controlled release of drugs using polyphosphazenes. They have made recent progress in their research on calcium phosphate ceramics and have opened up new drug delivery approaches with polyphosphazene polymers.

Bone Material Studies

Biomaterials are probably used more in dentistry and orthopedics than in other medical professions. In addition, both professions work almost exclusively with hard tissue. Biomaterials are used to restore the normal function of bone; for repair, replacement, or augmentation of deficient tissue; and for the support of prostheses. To be considered successful as a biomaterial, a substance must meet several very exacting conditions. In particular, it must have the capability of being fabricated into functional shapes, and it must not be toxic. When one places a biomaterial in a living tissue environment, an artificial interface is created between the living tissue and the biomaterial. Ideally, the interface between the implant and the surrounding tissue should behave similarly to a normal biological surface present at the same place in the healthy tissue. The ultimate goal of implantation of biomaterials in the skeleton is to reach full integration of the nonliving implant with the living tissue. The extent to which the bone-implant combination will be able to function as an integrated mechanical unit depends largely on the mechanical and physiological characteristics of the living bone, the chemical and physical properties of the implant, and the interaction between the bone and the implant.

Bone is a mineralized connective tissue, the main constituent of which is a conglomerate of calcium salts; its composition is still not fully understood. Approximately 60 percent of the mineral bone is crystallized calcium hydroxyapatite. The organic component is primarily collagen. The physical properties of bone result from a combination of the collagen's tensile strength and the compressive strength of the calcium hydroxyapatite and the other calcium salts. It is thought that the collagen and hydroxyapatite are bound together very tightly and that this is what gives the bone matrix its unique mechanical properties. Bone, being living tissue, is porous to allow penetration of nutrient material into its vascular system. Thus, any material that is to be used as a bone substitute must have a specialized architecture and some rather distinct properties.

De Groot's group has turned its attention to calcium phosphate ceramics in an effort to find a suitable material to replace or augment bone in several parts of the skeleton. In some instances they are interested in a material that will maintain its integrity indefinitely in the body, and in others they want a material that will slowly degrade as it is replaced by natural tissue. One characteristic of ceramics with calcium phosphate surfaces is their ability to form a tight bond with bony tissue. They are, therefore, called bioactive bioceramics, in contrast to other ceramics that do not have this property.

Another important feature of calcium phosphate ceramics is their porosity. Depending on the technique used for sintering (fusing), one can create pores with a diameter greater than 100 μ that will allow bone ingrowth, or pores of only a few microns that do not allow such ingrowth. The larger pore size also effectively enhances the available surface for cellular interaction with surrounding tissue. Finally, the tensile and compressive strength of these ceramics is very close to that of natural bone, so there is not a large mismatch in strength when they are combined with bone. Two methods have been suggested by de Groot and his coworkers to prevent fatigue failures in ceramics. The first is reinforcement with metallic structures of high fatigue resistance to stop small cracks from growing into large ones. The second is prestressing, that is, keeping the ceramic device under a permanent compression, thus preventing small cracks form forming and existing small cracks from growing. Both of these methods require that other materials be added to the bioceramic, giving composite structures.

Perhaps the most important feature of these bioceramics is their excellent biocompatibility, not only with bony tissue but with epithelial and connective tissue as

well. When these material are implanted in bone, a tight bond results. It isn't even necessary to have an exact fit between the implant and the bone, for new bone grows within a few weeks to fill the spaces.

In fact, Denissen and de Groot (1979) showed that the bond that develops between bone and these ceramics is usually so strong that the implant cannot be removed without fracturing surrounding bone. The group has done studies in which these ceramics were used in rats, rabbits, dogs, and guinea pigs; in such sites of implantation as the alveolar bone (for dental purposes), vertebrae, long bones, and the skull; and for replacement of auditory ossicles (de Groot, 1981). All their studies have shown conclusively that calcium phosphate ceramics are not rejected by the host but are integrated into the bony tissues at the implant site.

In terms of biocompatibility, they have found that there is no difference between very dense material and that having pores large enough for bone ingrowth. C.P.A.T. Klein, a veterinarian who has recently taken a Ph.D. under de Groot and has remained in the department, has found some slight differences in the number of macrophages around the surfaces of implants of different types of calcium bioceramics.

Normal bone is continuously replaced (remodeled) in living subjects. Old bone is degraded and replaced by new cells. This process is not fully understood yet. It seems reasonable to assume that calcium phosphate ceramics undergo a similar degradation when implanted. Klein studied this phenomenon extensively using rabbits. She placed cylinders of the ceramics in the tibiae and evaluated the extent of biodegradation by radiography, light and fluorescent microscopy, microradiography, and porosity measurements. She found that three factors dominate biodegradability: crystallography, stoichiometry, and the degree of porosity. However, the literature does not show agreement on these or any other factors.

Klein also found that immune system mechanisms may influence biodegradation as does the ultrastructural geometry of the sintered particles making up the ceramics. In terms of the immune process, she noticed that certain ceramics act differently with respect to immunologically important serum proteins. It is possible that phagocytosis is affected.

Finally, Klein looked at the biodegradation behavior of calcium phosphate materials in subcutaneous tissue by implanting disks under the skin of rabbits. Here again, the bioceramics were noninflammatory and nonosteogenic. They were completely biocompatible. The extent of biodegradation was determined by light microscopy and macroporosity measurements. She concluded that the biodegradation behavior of calcium phosphate materials in subcutaneous tissue differs from that in bone. In the soft tissue it seems to occur primarily by dissolution and phagocytosis.

Drug Release Studies

The major focus of drug-related research over the years has been on the development of potent drugs with new types of biological activity. Though this type of research continues, increasing attention is being devoted to the manner in which these drugs are administered. This has given new impetus to research into controlled release, making it a rapidly expanding area in biomaterial (see *ESN* 38-10:526-530 [1984] and 39-5:187-190 [1985]). Much of the research has centered around various classes of polymers. Recently a new class of polymers with an inorganic backbone has emerged as a candidate material for application as a drug deliverer. These materials (polyphosphazenes) seem to be able to act either as carriers of drugs, as bioerodible implantable material for prosthesis, or both.

The use of a bioerodible polyphosphazene as a temporary substitute for hard tissue seems extremely attractive since degradation of the backbone produces phosphate and ammonium ions which, at physiological concentrations, are harmless. Several other features of this class of compounds have compelled de Groot's group to study them:

1. The compounds are synthesized through a unique process that allows the polymer to be made with special characteristics for specific applications.

2. Preliminary tests of some of the nonbioerodible polyphosphazenes – i.e., those that are stable in a biological environment – indicate that they have good biocompatibility.

3. The synthesis of the polymer does not require initiators, stabilizers, or plasticizers which often cause toxicity problems with polymeric biomaterials.

The first project involving polyphosphazenes has been an attempt to develop a bioerodible carrier system of the agents that influence bone formation and resorption. This type of device would act as a prosthesis and disappear as the formation of new bone occurs. Ideally, the degradation should proceed at the same rate as new bone is formed. In addition, it was thought feasible to incorporate a bone-active material that is released as the polymer degrades. This bone-active material could either be a substance that stimulates bone formation or retards bone resorption. To ensure controlled release of the active compound upon polymer degradation, it was proposed to link it directly to the polymer chain.

To study the feasibility of this concept, C.W. Grolleman developed an erodible "pendant" system; this is a system in which the drug is chemically bound to the polymer. Actually two methods of attaching the drug to the polymer were tried. In one case the drug was bound di-

rectly to the polymer, and in the other it was held by a spacer. In either case, the drug was released uniformly as the polymeric matrix degraded. The use of a spacer has at least two advantages if it works:

1. It expands the scope of the concept by providing alternate means whereby the drug can be attached to the polymer. There may not always be a functional group within the drug molecule suitable for reaction with the polymer chain.

2. It gives a maximum degree of substitution by reducing the possible steric hindrance of bulky drug molecules.

The release rate can be varied by changing the nature of the phosphorus-spacer bond.

Grolleman chose naproxen [(+)-2-(6-methoxy-2-naphthyl) propionic acid] as the model drugs. This molecule is a relatively simple one since it has only on reactive functional group. Naproxen and its main metabolite (desmethyl naproxen) can easily be detected and quantified by ultraviolet or fluorescence spectroscopy. They can be separated from plasma or urine to obtain pharmacokinetic profiles of the drug.

The first part of Grolleman's studies focused on the synthesis and characterization of a copolymer containing naproxen linked to the polymer chain via a spacer, lysine ethyl ester. He did not attempt to achieve release of naproxen to an extent that a therapeutic level could be reached since this was not the purpose of this early phase of the research. He was mainly trying to prove the applicability of the concept of using polyphosphazenes as bioerodible drug carriers. Polyphosphazenes of different molecular weight as well as polymers having a different substitution were synthesized and characterized by spectroscopic methods and gel permeation chromatography.

The *in vitro* release experiments and their mathematical description formed the second part of Grolleman's study. A zero-order release rate was found when pellets of the prepared polymer were put into buffer (ph = 7.4) at 37°C. The observed release rate depended upon the degree of substitution as well as molecular weight of the polymers he prepared. The drug was totally released at 60°C. Upon release, the polymer matrix gradually disappeared.

The third part of this study was a series of *in vivo* experiments to test the efficacy and feasibility in animals. A pellet of the naproxen-containing polymer was implanted subcutaneously in rats. Histological examination of the implant site showed that a thin capsule was formed around the polymeric device but no signs of an inflammation reaction were observed. Thus, the conclusion was drawn that the implant was well accepted by the body tissue involved.

Conclusion

The group at Free University is moving in a number of directions and is anticipating work in still other areas. This appears to be a very active and innovative group that will certainly be heard from in the biomaterials research area.

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Biological Science Under TNO–The Netherlands Organization for Applied Scientific Research

by Claire E. Zomzely-Neurath. (This article was originally published in June 1986 [ESN 40-6].) Dr. Zomzely-Neurath is the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research's London Branch Office. She is on leave until July 1989 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.

TNO was established by law in 1930 with the aim of ensuring that applied scientific research is put at the service of the community in the most efficient manner possible. TNO is a fully independent, nonprofit research organization with a staff of about 5000 and an annual research volume of approximately 1560 million Guilder (~$220 million). In the past year, TNO executed some 20,000 contract research and development projects, commissioned by about 6000 Dutch and foreign clients. TNO's major target group is trade and industry, the small

and medium-sized firms in particular. Other important target groups are: central and local authorities, private organizations, and individuals. In some cases, collective research is carried out for specific branches of industry. (For detailed information on TNO's organization, policy, and funding see *ESN* 38-8:438-440 [1984].)

TNO's main fields of interest are industrial technology, energy, the environment, food and nutrition, health, and defense. In this connection, TNO's activities can be subdivided into three major categories: explorative research, applied research, and the transfer of know-how. The TNO consists of eight divisions (each with its own special field of research) comprising about 35 institutes.

The quality of research carried out at the various TNO institutes is excellent. In many instances, the research is at the basic level although areas of investigation which are emphasized are based on potential practical application. It is beyond the scope of this report to describe all the research at TNO. Thus, only selected areas of investigation are presented in the following section.

Biotechnology

In its research into the possibilities of extending the active life of enzymes, the Division of Technology for Society has achieved some interesting results from the application of amylase derivatives as stabilizing carriers for the immobilization of enzymes. The specific surface area of metastable amylase proved to be quite large, and the preparations obtained by means of complexing were 100 percent soluble in cold water. By encapsulating glucose isomerase in amulose-ether gels with an amylase-ether concentration of more than 35 to 40 percent, a half-life extension with a factor of 2.5 was obtained, compared with concentrations lower than 35 percent. A problem which remains is the presence of amylase in the solution of the glucoseisomerase preparation which decreases the mechanical stability of the catalyst particles. Work on the solution to this problem is continuing. By making succinate and, subsequently, cross-linking alpha-chymotrypsin using a specific method, an increased in thermal stability was achieved which, compared with the natural enzyme, is better by a factor of 20 than reported in the literature.

A number of models have been developed for describing the mass transfer processes in immobilized enzymes. These are now being tested experimentally with invertase immobilized on alginate spheres.

In order to obtain greater efficiency of the Penicillin/Acylase/Urease systems, experiments were carried out to optimize the quantities of enzymes and substances. It was found that the method of internal pH control leads to a quicker and higher conversion of penicillin than does the method which makes use of an external buffer.

Another development, and one which has equally interesting industrial potential, is the catalysis of chemically difficult esterification reactions. It proved possible to demonstrate that with the right choice of immobilization of the enzyme carboxylesterase and the other reaction conditions, methanol could be esterified to methyl acteate. This techniques is used to prepare interesting flavor and odor compounds in a natural way. Initial experiments with so-called "reverse micelles" indicated that this system can also be useful for two-phase reactions. Cholesterol oxidase, for example, was found to have a much higher activity than claimed by the manufacturer. These results would appear to be of importance for industrial application. For research into a better preparation method for technical alcohol, a modified upflow fermenter was constructed in which, among other things, there was improved sedimentation of the floculated micro-organism. An analysis and control program was developed for research with this fermenter whereby sucrose, glucose, fructose, and ethanol concentrations can be followed simultaneously as a function of time. Experiments with a special strain of *Zymomonas mobilis* gave a conversion of 99 percent at 100 g/l glucose and 7 percent higher yield than with the usual strain *Z. mobilis*.

Membrane Technology

In support of a project for the enzymatic hydrolysis of paper, studies were carried out to concentrate the dilute glucose solutions thus obtained. The method was one developed and patented by TNO, in which hyperfiltration membranes with both high and low retention are used. After experimental research on model solutions, a computer simulation program was developed to determine the optimum configuration at minimum energy consumption. Compared with multieffect evaporation, energy consumption which is lower by a factor of 8 appeared to be possible. The experimental results were in accordance with the theoretical basis. However, a number of practical problems had to solved, since in processing paper hydrolysate a number of other substances are present which have a greater retention than glucose. Work is continuing on a solution to these problems. In the continuous production of ethanol in a fermenter using *Z. mobilis*, one of the problems is how ethanol can be separated and glucose can be retained. With the choice of the right membrane, it proved possible to achieve this goal and to control the mass balances.

Recombinant DNA Research

Research in this area is done by a number of institutes. Originally, this work was carried out only in the Medical Biological Laboratory, but now several institutes (the Radiobiological Institute, the Institute for Experimental Gerontology, the Primate Center, and the Gaubius Institute for Cardiovascular Diseases) have to-

pics in their research program which require the use of recombinant DNA (rDNA) techniques. A great deal of effort is devoted to the development of vaccines. The Medical Biological Laboratory has cloned so-called "auxiliary proteins" which are of importance for the eventual preparation of a polio vaccine. In collaboration with the Biogen Company, the Primate Center has tested the first active recombinant DNA hepatitis B vaccine in chimpanzees. The other forms of hepatitis (non A, non B, and delta) are also being studied.

The other DNA research currently being undertaken is primarily concerned with the area of genotoxicity (damage caused to DNA which has already occurred. In the area of host-vector systems, progress have been made with Aspergillus. This fundamental research is essential in order to achieve the optimum production of rDNA products.

Immunology

Immunological research is carried out by a number of institutes within the Division for Health Research. The work is aimed at solving both immunological and nonimmunological problems using immunological techniques. The wide-ranging nature of this research is illustrated by the number of different applications of monoclonal antibodies (Mabs) in the program of the various institutes. In the Institute for Experimental Gerontology, Mabs are produced in connection with the early detection of tumors and also for the detection of small quantities of bacterial toxins in food.

In the Primate Center, Mabs are produced as tracers against certain sub-classes of white blood corpuscles which are a factor in the rejection of foreign tissue. In the Gaubius Institute for Cardiovascular Diseases, Mabs are produced against hormones and apoproteins for use in basic research studies and in assay procedures.

The organ and bone marrow transplant research within the so-called "REP" group (Radiobiological Institute, Institute for Experimental Gerontology, and Primate Center) has acquired a considerable reputation in the field of preclinical research (in rhesus monkeys). In this work, Mabs play an important part, both diagnostically and therapeutically. It has been shown that certain Mabs from mice, directed against human tissue determinants, can be used to prevent the impending rejection of a kidney transplant. The immunological research is also carried out in conjunction with genetic research in view of the hereditary transmission of certain tissue characteristics which can predispose a person to disease. In this context, work is being carried out with rhesus monkeys using model systems for rheumatism, multiple sclerosis, and AIDS.

The Central Institute for the Breeding of Laboratory Animals supplies laboratory animals to customers outside TNO (industry, universities, and other institutions). The center also produces special laboratory animals for specific purposes closely linked to the program of various institutes. In the field of the breeding and maintenance of rhesus monkeys and chimpanzees, the TNO Primate Center occupies a unique position in Europe. There is a clear tendency to concentrate research on nonhuman primates where the most expertise is available. This means that clients often subcontract their work to the Primate Center. An isolation building developed by TNO is available for carrying out tests under conditions of strict isolation. In this building, work on primates involving viruses and other potentially dangerous material can be carried out under safe conditions.

Ionizing Radiation and Cancer

The Radiobiological Institute's research program is concerned with the role of ionizing radiation in the genesis and also in the treatment of cancer. Particular attention is paid to the possible effects of regular exposure to relatively small amounts of radiation. Among the methods used are tissue-culture techniques which are extremely useful in investigations into the occurrence of malignant changes in cells after exposure to radiation. Epidemiological data from fundamental research that relates to the occurrence of cancer in humans after exposure to relatively high doses of ionizing radiation are used to calculate the risks of the occurrence of cancer at low doses.

The Radiobiological Institute also does a great deal of fundamental research into the treatment of cancer. Because of the institute's close links with the Rotterdam Comprehensive Cancer Center, Dijkzigt Hospital, and the Roterdam Radiotherapeutic Institute, the results obtained from the research are quickly available to the medical specialists concerned. The institute is also taking part in a combined experimental and clinical research program in which the use of heat in combination with radiation is studied in connection with the treatment of certain types of cancer. One of the Radiobiological Institute's important tasks is the preparation of a cancer registration system for the entire Rotterdam region.

In the treatment of a number of malignant blood diseases (such as leukemia) the use of bone marrow transplants is part of the therapy of choice. For this purpose, it is important that the parent cell of the bone marrow is isolated as completely as possible. Using advanced cell separation equipment it has proved possible to identify this cell. It is now possible to study the role of the parent cell in leukemia caused by radiation.

Rehabilitation Technology

Concern for the situation of disabled people in the Netherlands has grown considerably during the past few

years. As a result, TNO has devoted more attention to research which benefits disabled people and to work on rehabilitation, particularly in terms of expansion and coordination of research. In this context, work carried out by the Institute of Medical Physics has been used as a foundation for further research. There are now 10 TNO institutes involved in rehabilitation research.

Nutrition and Food

Virtually all TNO research in the area of nutrition and food is carried out by the Division for Nutrition and Food Research. Among the important aspects of the division's work on basic and luxury foodstuffs are quality, hygiene, toxicology, and technology.

Nutrition Research

An important project carried out by the Institute of Toxicology and Nutrition concerns the setting up of a nationwide system for the continuous monitoring of the nutritional status and dietary pattern of various sections of the Dutch population. In the initial system, attention was concentrated on the elderly. Blood samples are analyzed for, among other things, vitamin B6 and components which are a measure of iron intake because a preliminary study showed that the blood iron level and vitamin B6 level were significantly lower in the elderly as compared with younger people.

Toxicological Food Research

There are numerous indications that nutrition could play a part in the genesis, course, or treatment of a number of diseases, including cancer. Studies have also shown that nutrition can have an effect on the hormonal system. Therefore, the institute set up a study into the effects which fat, protein, carbohydrate, etc. have, via the hormonal system, on two of the most common forms of cancer; i.e., breast cancer and cancer of the prostate. Data on hormonal reactions to nutrition are obtained by determining androgens, estrogens, and prolactin in blood plasma, and androgen and estrogen receptors in mammary and uterine tissue of rats. A start has also been made on a large-scale experiment in which the effect of the amounts of fat and linoleic acid on existing carcinogen-induced tumors is being investigated. A series of different feed compositions is used so that interactions between the two elements can also be observed.

Some nutritionists have reported that lactobacilli in foods such as yogurt, cheese, sausage, and sauerkraut provide protection against cancer of the intestine. This was investigated in rats by researchers at the Institute of Toxicology and Nutrition. The production of glycocholic acids, the activity of certain enzymes and the bacterial composition of the feces – factors which play a part in the genesis of intestinal cancer – did not show any significant differences in the test group. However, further research is being carried out to find out whether the incidence of induced tumors is affected by the diet.

Food hygiene, food analysis, and technology are additional areas of research by the TNO Institute of Toxicology and Nutrition.

Conclusion

TNO, The Netherland Organization for Applied Scientific Research set up by the Dutch government, provides a means of transferring research know-how to industry and government agencies quickly and efficiently. The biological research carried out by the institutes of the TNO organization is of high quality both at the basic and applied levels.

3/19/86

COMPUTER SCIENCES

Work at Eindhoven on Formal Aspects of Real-Time Systems

by Krithi Ramamritham. Dr. Ramamritham, a Professor of Computer Sciences at the University of Massachusetts, is on sabbatical leave at the Computing Laboratory, The University of Newcastle-Upon-Tyne, UK.

Real-time systems are characterized by the fact that the correctness of the system depends not only on the logical result of computation, but also on the time at which the results are produced. Examples of such systems are

command and control systems, process control systems, flight avionics systems, and future systems such as the space station and SDI. Because of the disastrous consequences that are likely to occur when such time-critical systems fail, it is essential that these systems be certified to work according to specifications. Currently, confidence in the functioning of a real-time system is unfortunately gained by extensive testing of the system in simulated environments. This approach is not very satisfactory since it does not guarantee to reveal all the "bugs" in a system. Such a guarantee is possible only via the use of formal specification and verification techniques. However, the need to deal with explicit timing-related properties makes this a difficult problem compared to (non time-critical) concurrent systems.

Researchers in Europe have begun to examine this problem, and promising approaches are being developed. Perhaps the group that has progressed the farthest in this area is the Theoretical Computing Science Group at the Eindhoven University of Technology in the Netherlands. This group, led by Professor W.P. de Roever, is part of the "Debugging and Specification of ADA Real-Time Embedded Systems" (DESCARTES) funded by the European Strategic Program of Research and Development in Information Technology (ESPRIT).

Driving Principles

So far, there are two principles that have driven the work at Eindhoven. The first is the principle of compositional program verification (de Roever, 1985). This principle is said to be satisfied if a program can be verified – with respect to a given set of specifications – on the basis of just the specifications of the components of the program; i.e., without re-examination of the internals of the components. The second principle is that program verification should proceed in parallel with program construction, i.e., a posteriori verification should be avoided. These related principles make it possible to apply hierarchical decomposition techniques not just to program development but also to program verification.

Program and Computation Models

Even though the goal of DESCARTES is to deal with real-time programs written in ADA, given the inherent complexity of ADA, researchers at Eindhoven have been working on Communicating Sequential Processes (CSP) as well as the (CSP-like) programing language OCCAM extended with constructs designed to capture time-related aspects. Since verification of CSP programs is fairly well understood, this is an expedient choice. CSP allows programs to be constructed in terms of processes that communicate via synchronous messages. The variation of CSP studied by researchers at Eindhoven involves the addition of a construct "delay d" that delays execution of a process by "d" units of time. Since this construct can appear in the guards (i.e., conditions imposed on the execution of statements) along with input/output statements of CSP, it can be used to program time-out situations.

While extended CSP provides the programing model, the computational model adopted is the so-called maximal parallelism model. Here, any ready process can execute immediately. The assumption then is that as many computation elements (processors) as needed are available. This is unlike the more commonly used interleaving model of computation where truly concurrent activities are mapped into a sequence formed by interleaving the concurrent activities. Hence information about the concurrency inherent in a program is lost when the interleaving model is used. It should be clear that the maximum parallelism model is a better model to reason about activities in real-time systems (since many of the activities do occur concurrently) but still does not completely model the (resource-constrained) real world.

Approaches to Verifying Real-Time Programs

There is a fundamental difference between traditional programs and real-time programs. They are typically nonterminating and are characterized by intensive interactions with the environment. Thus, standard specification and verification techniques based on preconditions and postconditions of programs and their components have to be extended. Two different approaches to this problem have been proposed by Eindhoven researchers.

The first, discussed in Koymans et al. (1985), is based on a linear history semantics developed for (the original) CSP. Processes in a real-time system are represented by prefix-closed sets of (state, history) pairs. The state indicates the values of the variables within the process. Histories are modeled as sequences of "bags" of communication assumptions leading to that state. (Bags are used instead of sets to model true concurrency, in particular, concurrent communication.) A communication assumption indicates the different communications that can occur in a given state, the variables involved in each, as well as the communications that cannot occur in that state. Time is modeled using a conceptual global clock and the passage of real-time is modeled by relating the n-th element of a history with the n-th tick of the clock. In other words, time is reflected by the length of the histories. Given the above tools, semantics of each programing language construct is specified in terms of a mapping from the syntax to (state, history) pairs. This mapping can be used to derive the overall observable behavior of a real-time program and determine whether it is equivalent to the desired behavior.

The second approach, discussed in Hooman (1987), specifies, for each process, its commitments and assumptions in addition to the pre- and postconditions. A commitment is an invariant specification concerning the real-time communication behavior of a process. It holds during (and after) the execution of the process. An assumption is used to describe the expected behavior of the environment of the process. The environment of a process includes other processes with which the process of interest communicates. Here again, time is modeled using a conceptual global clock. Defining the semantics of language constructs involves defining a function that assigns execution times to programing language constructs. Timing-related specifications of the processes are with reference to the global clock and can appear in any part of the specification of a process. Two processes can be composed (to execute in parallel) if the assumptions of one about its communications with the other are consistent with the commitments of the other with respect to these communications. Such a composition yields overall assumptions and commitments of the newly composed process. Such compositions are carried out until the overall system behavior can be obtained and checked against given specifications.

Appropriate Extensions to This Work

With the above tools, compositional proof systems for real-time programs have been developed. Further extensions are necessary to capture the more realistic aspects of real-time computing. Specifically, both the programing model as well as the computational model need to be extended. Even though some of the real-time constructs of ADA can be simulated using the constructs in the variation of CSP adopted thus far, it is necessary to extend it further to make the proof system applicable to nontrival ADA programs, especially those that involve dynamic process creations.

Perhaps more important is the need to go beyond the maximum parallelism model. Real-time systems utilize complex scheduling schemes to meet the variety of constraints that are typically imposed on them. These include timing constraints on the processes, such as periodicity constraints and deadlines, resource requirements of the processes, and precedence constraints among processes. Further, processes are characterized by their levels of importance, typically specified in terms of their priorities. The goal of the scheduling algorithms is to map the processes to the computational elements so as to meet the timing constraints while fulfilling other requirements. Thus, meeting the timing requirements depends on the "correctness" of the scheduling algorithms. The ideal way to formally analyze a real-time system is to consider the scheduling algorithm used while verifying a given real-time program. However, this generality will, in all probability, produce severe theoretical problems. Some of these arise since the mapping of real-time processes with complex constraints to limited resources is an NP-hard problem – i.e., is computationally intractable. Hence it is perhaps better to start by extending the current maximum parallelism model with simple scheduling algorithms such as those that are priority-based or deadline-driven.

To conclude, a good beginning has been made by researchers at Eindhoven to deal with the formal specification of real-time systems. While a number of practical issues remain, the current directions appear very promising.

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5/12/88

CONTROL THEORY

System and Control Theory at CWI, Amsterdam

by Daniel J. Collins. Dr. Collins was the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office until June 1988. He has returned to the Naval Postgraduate School where he is a Professor of Aeronautical Engineering.

The Center for Mathematics and Computer Science (CWI) is the research institute of the Stichting Mathematisch Centrum which is sponsored by the Netherlands Organization for the Advancement of Pure Scientific Re-

search (ZWO). The goal of CWI is to do fundamental and advanced research in mathematics and computer science with special attention to those area that may have relevant applications. Professor P. C. Baayen is the scientific director of a staff of over 200 with some 120 people directly engaged in research. CWI has also been designated a center of excellence in the computer science area for the Netherlands. The research is organized into eight scientific departments which include pure mathematics, applied mathematics, mathematical statistics, operations research and system theory, numerical mathematics, software technology, algorithms and architecture, and interactive systems. An effort is made to have considerable overlap and collaboration between departments. Some of the department heads also have joint appointments in different universities, and contract work in technology transfer and collaboration with industry is emphasized.

In this report I shall highlight the work in systems and control theory at CWI. I will also comment on what I thought were some particularly interesting projects in numerical mathematics, applied mathematics, and software development.

Systems and Control Theory

The systems and control work is carried out in the Department of Operations Research and System Theory, but part of the staff of this group of eight includes Professor M. Hazewinkel, who is also head of the pure mathematics department. The department has eight research projects which involve cooperation with other research institutes, most of these in the Netherlands.

I talked with Dr. J. H. van Schuppen, who earned his doctorate at the University of California at Berkeley. He is concerned with stochastic system theory and is presently working with Professor H. Kwakernaak of Twente University on modeling and simulation of freeway traffic flow. Some years ago the Netherlands installed a freeway control and signalling system which consists of sensors buried in the concrete every 500 meters, matrix signal boards above the freeway with advisory speeds, and computer and communication equipment for processing all the signals. One of van Schuppen's doctoral student's, S.A. Smulders, has modeled the system and traffic using essentially a hydrodynamic model for the traffic with a view to improve traffic flow and prevent congestion (S.A. Smulders 1987). This work was reported on in the Tenth International Symposium on Transportation and Traffic Flow in Boston, July 1987. As a result of R.E. Kalman's criticism of stochastic models for econometrics, van Schuppen has developed some new stochastic control problems and is focusing on the factor analysis model. Van Schuppen is also concerned with overload control of communication systems (Boel, and van Schuppen, 1986).

The department's Dr. J.M. Schumacher is concerned with deterministic system theory and the development of geometric theory of linear and nonlinear systems. Schumacher is also involved in the supervision of the Foundation for Technical Science (STW) project at Groningen on the analysis of large-scale space structures. One of Schumacher's recent publications is on residue formulas for meromorphic matrices. The publication is directly motivated by engineering consideration. In the vibration of a large-scale system one is not only interested in the resonance frequencies but also in the participation matrices that govern the distribution of energy over the various resonance modes. These matrices appear as residue matrices for certain meromorphic matrix-valued functions.

An interesting problem in adaptive control is under consideration by J. W. Polderman in his analysis of algorithms for adaptive pole placement. Polderman has reported on an discrete algorithm for SISO systems which does not require externally excited inputs and where there is no a priori information on the system outside of its order. Pole-zero cancellation of the estimates is avoided by introducing a finite number of special inputs. The adaptation of the controller parameters does not depend on the stability properties of the system.

Numerical Mathematics

In the Numerical Mathematics Department work by P.W. Hemker on multigrid methods (*ESN* 39-6:267 [1985]) as applied to Euler and Navier-Stokes equations and semiconductor equations is continuing. In particular, Hemker is investigating a method that considers the Navier-Stokes equations at large Reynolds number as a perturbation to Euler flow. A defect correction technique applied to the Euler solver generates a solution to compressible Navier-Stokes equations (Rusch, 1986). J.G. Verwer, W.H. Hundsdorfer, and F.W. Wubs are continuing their work on the discretization of initial value problems. A variety of equations have been considered including the Navier-Stokes equations, shallow water waves, hyperbolic equation, and integral equations. As part of the incompressible Navier-Stokes investigations Verwer and Ten Thije Boonkkamp have investigated the odd-even hopscotch scheme for numerical integration (Boonkkamp, 1987).

Another interesting development in the department is the use of the computer as a research tool in the investigation of pure mathematical theories. H. Te Riele is, in particular, using computers to investigate aspects of long-standing number theory problems. This effort involves distribution of primes and the Riemann hypothesis. Finally, work is progressing in the department on the development of numerical software in the ADA language and

in the development of new algorithms for vector and parallel processors.

Computer Science

In the past few years there has been a large effort in the computer science and informatics area, and the Department of Software Technology has gone from about 20 to 30 people. This governmental emphasis on computer science is typical in Europe. The department is involved in several ESPRIT projects which are concerned with parallel architectures and languages and with process algebra with a view to verification, specification, and design of distributed software. In this department an effort is being developed in expert systems and in other aspects of artificial intelligence. One of the ESPRIT projects is concerned with the specification of or generation of interactive programing environments (GIPE). In this project, P. Klint, along with others, is developing a common environment with defined common interfaces, various language definition formalisms and the global environment generator (Bergstra et al., 1987). The second country involved in this project is France (SEMA-METRA).

Applied Mathematics

The Applied Mathematics Department, headed by Professor H. A. Lauwerier, who has a joint appointment with the University of Amsterdam, is concerned with nonlinear analysis and biomathematics, stochastic aspects of dynamical systems, and asymptotics and applied analysis. Lauwerier has just published a book on the generation of fractals on a PC computer. In biomathematics, O. Diekmann was editor of a book on the dynamics of physiologically structured populations (Metz and Diekmann, 1986). There appears to be a strong effort in the department on the analysis and spread of plant disease, that interest reflected in a recent publication by J.A.J. Metz is on the asymptotic speed of traveling epidemic waves.

Conclusion

CWI is truly a center of excellence in the area of computer science and mathematics in the Netherlands. The institute shows a nice balance between pure and applied mathematics. CWI has excellent contacts with other research institutes and universities in Holland. The institute would be a good starting point for anyone interested in what activity might be going on in the Netherlands in a given problem of mathematical analysis.

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7/14/87

FLUID MECHANICS

Fluid Mechanics at NLR

by Eugene F. Brown. (This article was originally published in July 1986 [ESN 40-7].) Dr. Brown was the Liaison Scientist for Fluid Mechanics in Europe and the Middle East for the Office of Naval Research's London Branch Office from September 1985 to September 1987.

The National Aerospace Laboratory (NLR) is the center for aerospace research in the Netherlands. It is located at two sites: in Amsterdam itself and approximately 100 km from Amsterdam in the Northeast Polder. At the present time the administrative headquarters and the majority of NLR's approximately 780 employees are located in Amsterdam. Since acquiring the 500-acre site in the Northeast Polder in 1958, however, activities have gradually shifted from Amsterdam. At the present time several departments of the Fluid Dynamics Division as well as the German-Dutch Windtunnel (DNW) are located there. My visit was to the site in Amsterdam.

NLR had its origins in 1913 with the formation of the Aeronautical Department of the Dutch Navy. It was organized into its present form as an independent, nonprofit organization in 1937. NLR's principal mission is to ren-

der scientific support and technical assistance on a non-profit basis to Dutch and foreign aerospace industries and organizations, civil and military aircraft operators, and government agencies concerned with aviation and space flight. NLR closely cooperates with the Dutch aircraft manufacturer, Fokker, in aircraft development under contract with the Netherlands Agency for Aerospace Programs (NIVR). In fact, Fokker depends entirely on NLR for scientific support. In addition, NLR assists Dutch aircraft operators (KLM, the Royal Netherlands Air Force, and the Royal Netherlands Navy) with the evaluation of aircraft and equipment and with technical problems in aircraft operations. For the Royal Netherlands Air Force, it operates a scientific research program planned on a rotating 5-year basis in the field of aeronautics. Finally, NLR contributes to the development of Dutch aerospace projects and projects for the European Space Agency and foreign aerospace industries.

At the present time approximately 70 percent of NLR's income is derived from research contracts and the remainder from subsidies from the Dutch government. Much of its current contracted activities are directed toward the needs of Fokker in support of its new F-50 and F-100 commercial aircraft development projects. Incidentally, this work is funded by the NIVR; however, because Fokker is a private company, this money must be repaid out of the company's profits.

The Fluid Dynamics Division performs a considerable amount of experimental studies for European industrial concerns and foreign governments. For example, approximately one-third of the aerodynamic work on the Concord was done in its Transonic Wind Tunnel (HST) located in Amsterdam. In addition, a large number of acoustics and aerodynamic studies for various European automobile manufacturers have been conducted in the DNW. At the present time tests are being conducted there for the US Navy's LHX helicopter program under the provisions of the Patriot Compensation Program. The large size of the DNW's test section (9.5x9.5 m^2) allows full- size automobiles to be rolled into the tunnel for testing.

The Fluid Dynamics Division

NLR is organized into five major divisions including: Fluid Dynamics, Flight, Structures and Materials, Space and Informatics Divisions. My visit was to the Fluid Dynamics Division. As can be seen from the NLR organizational chart, Figure 1, the Fluid Dynamics Division is divided into six departments: Incompressible (Low-Speed) Aerodynamics, Compressible (High-Speed) Aerodynamics, Propulsion Aerodynamics, Aeroelasticity, Theoretical Aerodynamics, and Wind Tunnel Instrumentation. In addition to the HST and the DNW, the Fluid Dynamics Division operates a 3x2.25-m^2 Low-speed Wind Tunnel (LST) and a Supersonic Wind Tunnel (SST) located in Amsterdam.

My host for my visit was Dr. H. Tijdeman, the Head of the Fluid Dynamics Division. After a brief review of the other departments, the discussion turned to the Fluid Dynamics Division which, at the present time, consists of a staff of 150, split about equally between Amsterdam and the Northeast Polder. Approximately one-third of the staff have masters or doctoral degrees. The remainder are technical and service staff.

Two departments within the division are located in Northeast Polder: the incompressible Aerodynamics De-

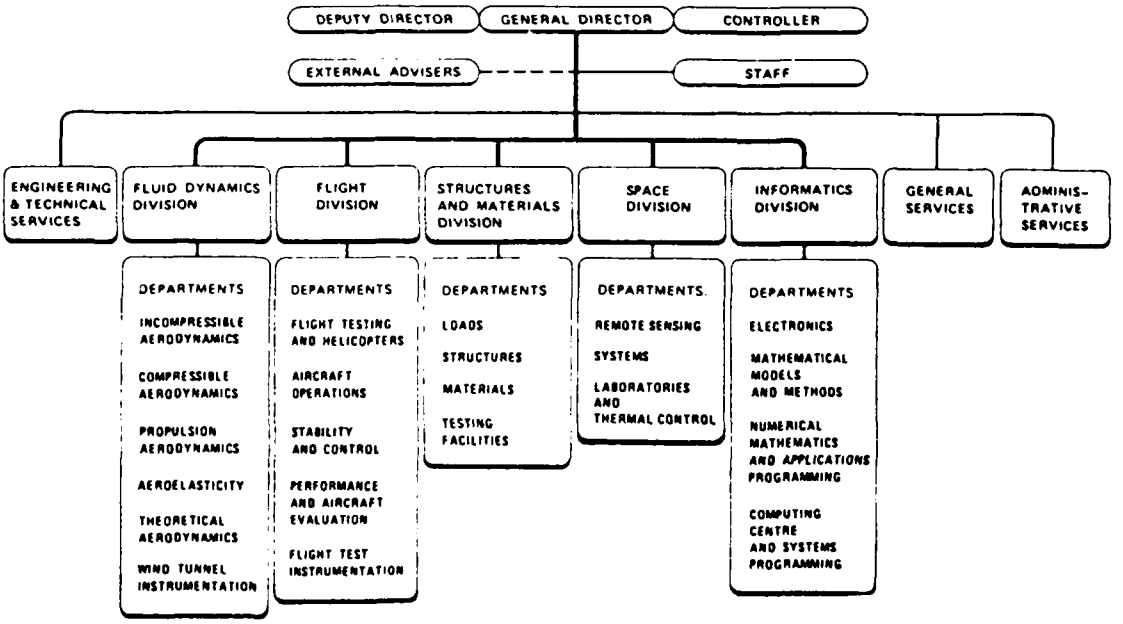

Figure 1. NLR organizational chart.

partment, and the Propulsion Aerodynamics Department. The Incompressible Aerodynamics Department is responsible for tests conducted in the LST and DNW tunnels plus an acoustics facility. Industrial, aircraft, ship, and automobile aerodynamics and acoustics tests are run by this group. An interesting Navy project was the aerodynamic tests of helicopter carriers in order to determine safe landing conditions. This was done for the Dutch and Norwegian navies.

The Propulsion Aerodynamics Department is responsible for aerodynamics and acoustic tests involving propulsion system integration in which it often runs tests involving powered engine simulators. At the present time such tests are going on to determine the aerodynamic and acoustic characteristics of a new six-bladed propeller for the Fokker F-50. In a proposed transonic extension of this work it is hoped that, with careful blade design, a high-performance, straight-bladed propeller capable of efficient operation at high Mach number can be built.

The Compressible Aerodynamics Department is located in Amsterdam. Its two principal experimental facilities are the HST and the SST. The HST is one of the principal aerodynamic facilities in Europe. It is a pressurized tunnel capable of stagnation pressures between 0.1 and 4 atmospheres and Mach numbers up to 1.25. Its test sections is 2.0x1.6 m^2 and is compatible with that of the SST (1.2x1.2 m^2); this enables the same model to be tested both in the HST and SST and gives NLR the unique capability of being able to carry out tests of the same model from incompressible conditions up to a Mach number of four.

The Aeroelasticity Department, also located in Amsterdam, is involved in both computational and experimental unsteady aerodynamics and flutter research. The group has carried out steady load measurements on the F-5 wing for the Air Force Wright Aeronautical Laboratories (AFWAL) and NASA and has made elasticity measurements on industrial structures such as bridges and dikes. They are presently carrying out pitching tests on the F-16 wing for General Dynamics (GD), Fort Worth, and AFWAL. These tests, which are scheduled to take place over the next 22 months, were described to me by Dr. Atlee Cunningham from GD who just happened to be at NLR during my visit. The tests will be carried out in the LST and will feature both small-amplitude, high-frequency oscillations typical of structural vibrations and large-amplitude, low-frequency oscillations typical of maneuver operation. Static pressure data will be taken with 42 pressure taps and loads will be measured with a six-component balance. Initial tests are planned at a Mach number of 0.3 with a series of follow-on tests to be conducted at transonic Mach numbers. The purpose of the project is to examine the vortex bursting phenomenon which occurs on wings of delta planforms at high angles of attack and high Reynolds numbers. These tests will be conducted with a mean angle of attack of 55 degrees. Because the vortex bursting phenomenon is poorly understood, extensive flow visualization studies using a pulsed laser sheet as well as global lighting have been planned to visualize the flow in cross-section over the entire wing. Although the ultimate objective of this work is to learn how to control vortex bursting at high Reynolds numbers, the immediate application of this work is to develop and improve Euler codes which are being written to predict the vortex bursting phenomenon.

Cunningham has an ONR contract to look at vortex bursting in a smoke tunnel and a 2x2 ft^2, high-speed water tunnel which is currently being built at GD. Eventually the results of the small- scale tests at GE will be compared with the NLR tests to investigate the effects of Reynolds number on vortex bursting.

NLR's Computational Fluid Dynamic Work

The bulk of the computational fluid dynamic work at NLR is conducted in the Theoretical Aerodynamics Department, which is headed by Mr. J. Slooff. At the present time he has a staff of 10, complemented by a group of approximately equal size in the Informatics Division which supports his activities in the areas of mathematical models and numerical methods. Slooff's group is responsible for writing analysis and design codes to support Fokker's aircraft production activities and to sell to other aircraft companies. In this latter connection they have developed codes for low-speed, multiple airfoil design; transonic airfoil design; boundary layer analysis; three-dimensional panel methods for complex subsonic configuration analysis; and inverse wing design. Figure 2 gives a schematic indication of the Division's computational capabilities. Some of the most important new work involves the modeling of surface waves, viscous/inviscid interactions, a new multigrid concept for panel methods, and a new field panel method.

NLR's principal computational facility is a Control Data Corporation (CDC) Cyber 180/855 mainframe computer supplemented by a link with a Cyber 205 at the University of Antwerp. Slooff said that the link was not very good and that he felt handicapped by the small memory size (1 megabyte). This situation should improve considerably, however, in the 1988-1989 time frame since NLR plans to purchase a Cray X-MP with a 2-megabyte memory and additional solid-state device (SSD) storage.

Slooff's close ties with Fokker have advantages and disadvantages. The advantage is, of course, that Slooff (through NIVR) is assured of a steady income. The disadvantage is that the activities of his group are highly constrained. For one thing, Fokker's interest is primarily in civilian aircraft, thus most of Slooff's work must be in connection with civilian rather than military projects. In addition, the intense activity at Fokker in connection with

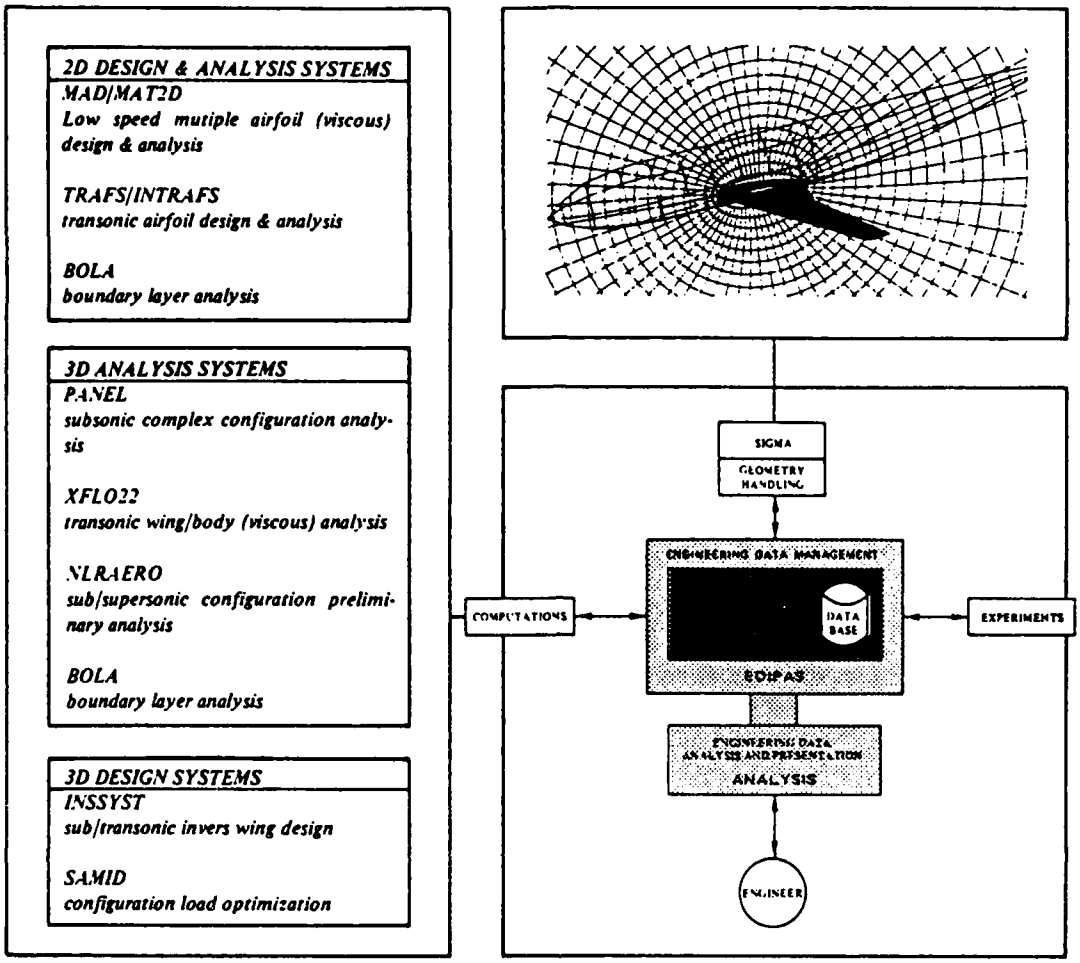

Figure 2. Computational fluid dynamics programs.

the new F-50 and F-100 projects has demanded so much of Slooff's time that his group has fallen behind in the development of new algorithms. This explains why his group has very little Navier-Stokes work going on and got started fairly late in the development of its three-dimensional Euler code.

Slooff is perhaps best known for his panel method calculations for wing design which he began in 1968. Since that time many refinements in the code have been implemented. In its present second-order-accurate form, it contains advanced singularity formulations and use of Dirchlet rather than Neumann boundary conditions. A multigrid capability has also been added which can be implemented either as a conventional accelerated convergence technique or as a means to reformulate the equations themselves. To reformulate the equations, grids of successively finer size are proposed leading to a banded matrix for the aerodynamic influence coefficients (AIC's). The banded nature of the matrices for the AIC's leads to significant savings in both storage and computational time. The initial estimates are that this technique will allow a panel method simulation to be worked out with N operations. This compares with N^3 operations which are required for present classical methods employing Gaussian elimination. If these estimates are correct, this means that computational time savings of several orders of magnitude can easily be achieved. Slooff calls this a multilevel integral evaluation (MIE) technique. A feasibility study has been completed which demonstrates the efficiency of the technique on a flat-plate air-foil problem.

Another new development is the use of field panel methods to calculate the compressible flow over the slats of a multielement airfoil in the low-speed (Mach = 0.2) takeoff and landing configuration. In these situations it has been found that Mach numbers as high as 1.6 exist on the slat which, combined with a resulting shock wave, invalidate the incompressibility assumptions inherent in classical panel methods. To simulate the essential nonlinearity of the compressible flow, the region on almost the entire suction surface and, in some cases, half of the pressure surface is surrounded by a C grid. In this region the dis-

tribution of source singularities is found by solving the full (compressible) potential equation by a fully conservative, finite volume technique. In the remainder of the flow, the conventional (incompressible) panel method is used. The resulting solution is therefore a combination of the field singularity distribution obtained on the grid and the surface distribution of singularities on the airfoil surface computed by the conventional panel method. Osher-type splitting combined with a multigrid method was used to accelerate the convergence of the field calculations. The advantage of the technique is that nonlinear simulation is attempted only in those regions of the flow field where compressible effects are expected. This has two advantages: it reduces the computational time and it simplifies the grid generation process. In the latter connection, this means that the complexities associated with generating and interpolating between the multiple grids used in conventional domain decomposition methods can be avoided.

In a recent article describing the field panel method, B. Oskam described the application of this method to a NACA 0012 airfoil and a four-component, high-lift wing (Oskam, 1985). The airfoil was discretized into 64 surface panels and a grid of 24x8 elements. Excellent agreement with finite difference calculations was seen. For the high-lift wing, the calculations were compared with experimental data and once again a good agreement was obtained except in the vicinity of the trailing edge where a strong shock (Mach = 1.6) on the upper surface of the slat resulted in the separation of the boundary layer. Discrepancies with the experimental data were, therefore, not unexpected. Obviously, additional attention needs to be given to the shock-wave/boundary-layer interaction problem if accurate calculations are to be obtained in such cases.

The program has been given the acronym MATRICS. An extension of this method to three-dimensional flows is presently underway. Mesh generators for more complex configurations such as the flow around an entire aircraft are being developed in collaboration with the Swedish Aeronautical Research Institute (FFA).

Slooff is famous for his calculations for Australia II, the yacht which won the America's Cup for Australia in 1983. It was widely acknowledged that it was the keel design which was responsible for the yacht's success. Slooff's contribution was the development of a panel method code for predicting keel performance which allowed surface wave effects to be taken into account. Slooff began working on a problem related to these calculations in 1977 in support of a SWATH-type (Small Waterline Area Twin Hull) vessel for the Dutch Navy. (The design for the Australia II was, in fact, managed by the Netherlands Ship Model Basin [NSMB], now known as MARIN, in Wageningen to which Slooff was a subcontractor.) Because of the military implications of this work, the reports on Slooff's calculations have not yet been released. His calculations are based upon the wave modeling concepts developed by C. W. Dawson of NSRDC. However, Dawson's scheme works only for low Froude numbers, and Slooff found that it was necessary to introduce an upwinding scheme on the free surface in order to produce a stable calculation for the infinite number case which he was considering. Slooff's intention is to combine this new surface model with his second-generation panel method.

Sloof also plans to develop a calculation method for limited regions of incompressible vortical flow such as found on partially stalled airfoils. Slooff is proposing to use a panel method which includes the vorticity by means of a Klepch formulation.

Finally we discussed the Theoretical Aerodynamic Department's plans for extending their quasi-simultaneous calculations of strongly interacting viscous flow to three-dimensional geometries. In contrast with conventional inverse and semi-inverse schemes, the quasi-simultaneous approach features the use of an interaction law which represents a linearization of the relationship between the velocity at the edge of the boundary layer and the displacement thickness. This equation is used in conjunction with an inverse method for the boundary layer in such a way that the combined solution represents a solution of the complete equation of the inviscid and viscous flows. The advantage of this technique is an order of magnitude increase in speed over semi-inverse methods and an increase in speed of two orders of magnitude over inverse methods. In contrast with other interaction calculations this technique (developed by A. Veldmann) is valid for compressible (as well as incompressible) flow, has a more advanced turbulence model, and includes the y-momentum equation in place of the usual boundary layer assumption of negligible transverse pressure gradient.

Conclusion

As should be clear from this article, NLR is not a basic research establishment. It is, however, performing work related to numerical modeling and algorithm development for a wide number of aircraft- and ship-related problems. Proposed developments in the area of multigrid methods (MIE), and surface-wave and vortical-flow modeling might be worthwhile considering for future Navy support.

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July 1986

Turbulence Research at the Eindhoven University of Technology

by Eugene F. Brown. (This article was originally published in July 1986 [ESN 40-7].)

At the Technical University of Eindhoven (THE) I visited the Fluid Mechanics and Heat Transfer Laboratory in the Department of Applied Physics. The group is fairly small, consisting of two professors and eight scientific staff members. However, they are extremely well equipped and are conducting several interesting projects in the fluid mechanics of turbulence. My host during much of the visit was Mr. C. Nieuwvelt, a member of the scientific staff.

The first stop on my tour was with Dr. J. Bessem, who is doing some experiments in a large (0.7x1.05 m^2) subsonic (2 to 6 m/s) wind tunnel. Of particular interest were the coherent structures near the wall where a dense water fog was injected through flush-mounted slots in the wall. The intention was to correlate flow visualizations with measurements of the wall shear stress obtained with flush-mounted hot film probes. The visualization was carried out by simultaneous illumination in both the horizontal and vertical planes. Viewing the test section at an angle during illumination produces a three-dimensional visualization of the turbulence structure. This work is a follow-on to a previous study in which an investigation of the velocity/shear-stress correlation was carried out using a hot wire anemometer and a thermal-type wall shear stress meter.

The objective of the experiments is to understand the coherent turbulence structures in the near-wall region. If the structure of near-wall turbulence is better understood, ways of modifying the structure (for example, through the use of longitudinal grooves) can be improved. This in turn might lead to improved ways for reducing aerodynamic and hydrodynamic drag. The wall shear stress meter consisted of five 70-μ-wide by 700-μ-long titanium elements vacuum-deposited on a glass substrate. The separation between the elements was 700 μ.

From the shear stress readings, Bessem constructed shear stress maps such as the one in Figure 1, which shows the passage of regions of high and low shear stress as the flow passes over the meter. It was hoped that these maps would reveal large regions of low shear stress which could be correlated with the appearance of the low-speed meandering streaks which had been seen in the flow visualization studies. What was seen, instead, were large regions of high shear stress. There might be two reasons for this. One is that the shear stress meter was too small to reveal the true dimensions of the low shear stress regions. Another reason might be the phase error of the wall shear stress measurements. A significant phase lag can be expected because of the large thermal mass of the glass substrate. In addition, the glass is responsible for a low signal-to-noise ratio because it absorbs much of the heat delivered to the film.

Figure 1. Typical shear stress map.

A. Koppius has been carrying out investigations of the near-wall turbulence structure in water in a 15x30-cm^2 water channel which was built specifically for this purpose. The water velocity in the channel is extremely small (only 10 to 30 cm/s). The Reynolds numbers are roughly equivalent to those achieved in THE's wind tunnel: $1x10^4$ to $1.3x10^6$ per meter. Based on the displacement thickness, the Reynolds number is approximately 2000.

Measurements were made with both three-wire, angled hot wire probes and a reference-beam anemometer system. In addition, the hydrogen-bubble technique was used to visualize the turbulent structures perpendicular to the plane of view. Multiple wires in the horizontal plane and a single wire in the horizontal and vertical plane were used. When the multiple and single wires were used together, photographs were made from an angle, thus producing three-dimensional images of the flow similar to those acquired with the laser sheet technique used in the wind tunnel studies. These images were enhanced by two-color illumination of the near-wall re-

gion. This was obtained with a colored filter in which the upper region was yellow and the lower region was blue. Color photographs then revealed motion in the direction normal to the floor of the channel. If, as shown in Figure 2, the blue portion of the light beam is the closest to the floor of the tunnel, a preponderance of yellow bubbles would disclose a region of high (positive) vertical velocity.

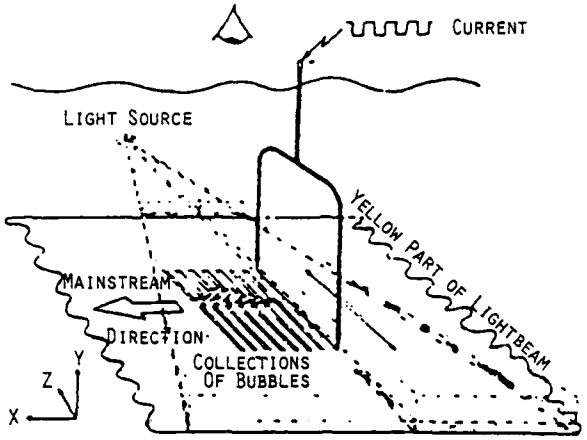

Figure 2. Two-color hydrogen bubble technique.

With this equipment and with a single, pulsed, horizontal wire, regions of relatively low stream-wise velocity and relatively strong positive vertical velocity were discovered. These so-called coherent structures were first observed by Kline in 1967 and named low-speed streaks. The vertical extent of the low-speed streaks was found to be a $y+$ of approximately 120. (This is considerably greater than that observed by other investigators; however, this difference might simply be ascribed to a difference in the coherent structure definition.) With the use of multiple wires located in the floor of the channel, these streaks were seen to meander slowly throughout the illuminated area, sometimes joining, sometimes separating, sometimes perturbed by other structures, but only a few of them ever having a visible beginning or end. One never sees an abrupt beginning or ending of a streak.

Perhaps the most controversial finding was the absence of Kline's bursting process. In an as yet unpublishd report by R. Blokland and K. K. Prasad, who collaborated with A. Koppius in this work, the bursting phenomenon is attributed to nothing more than the continuous vertical and span-wise undulation of the low-speed streaks. It is claimed, therefore, that the proper interpretation of previous dye injection and hydrogen-bubble experiments is not that bursting took place as claimed, but that the apparent bursting is simply the detection of a continuous process in which the visualizing medium is first sucked into the low-speed streak, lifted up, and transported through the streak away from the wall.

Work is continuing to examine the relative effectiveness of grooved plates in organizing the meandering near-wall turbulence structure, thereby reducing drag. For this purpose Koppius has designed an inductive-type drag balance which has been mounted in the floor of his water channel. Since the expected reduction of drag due to the grooves is only about 4 percent, extremely careful measurement of the drag forces is necessary. Even with a fairly large (approximately 40x12 cm^2) plate, displacements on the order of only 100 microns are expected. In such situations elaborate precautions must be taken to control the effects of thermal expansion caused by spurious temperature fluctuations. In fact it seems that the temperature must be controlled to within 0.05°C. Even with a refrigeration system installed to remove what would ordinarily be regarded as the inconsequential temperature increase due to the pumping of the water through the channel, repeatable measurements could not be made. A more accurate temperature control system including possibly better thermal insulation of the balance may be necessary before reliable measurements can be made.

Conclusion

I was impressed with the variety of experiments under way at THE in the area of turbulence-structure research and control. At the present time it seems that their research is well funded and that they lack neither for facilities, nor instrumentation, nor personnel. There are some signs that this might change, however. At the present time the Dutch technical universities have sustained deep cuts in their instrumentation budgets and the traditional 5-year engineering program has been reduced to 4. This, combined with attractive job offers which the 4-year candidates are receiving (this year's graduating class is the first to have gone through the new 4-year program), might mean that the Dutch universities will be hard pressed to continue their research programs at their current levels. Provided that THE is not too severely impacted by these changes, I anticipate that the Fluid Mechanics and Heat Transfer Laboratory will continue to make significant contributions to the field of turbulence research in the years to come.

July 1986

Turbulence Research at the Delft Hydraulics Laboratory

by Eugene F. Brown. (This article was originally published in April 1986 [ESN 40-7].)

The Delft Hydraulics Laboratory (DHL) was founded in 1933 as an agency of the Netherlands government. Its activities are conducted both at its headquarters in Delft and at DeVoorst in the Northeast Polder. The total number of DHL personnel is 535. Approximately one-third of these have masters and doctoral degrees. The principal activity of the laboratory is coastal hydraulics, and it conducts research similar to that done at the French National Hydraulics Laboratory (LNH) in Paris (ESN 40-4: 136-138 [1986]). In addition to its work in coastal, estuary, and fluvial hydraulics, it is involved in matters concerning water resources, the environment, and cutting and dredging technology. Some of the best known examples of its hydraulics work are its design of the flood barrier in the East Scheldt and its delta model of the Southwest Netherlands. It has several wave basins, flumes, wind-wave facilities, and pump testing circuits. For its saline intrusion work it has a seawater manufacturing facility capable of producing salt water with a specific gravity of up to 1.19.

As with LNH, DHL has a number of computer programs which it uses in its hydraulic studies. Some of these models are described in Figure 1. The program ODYSSEE was, in fact, jointly developed between LNH and DHL and is an example of the close cooperation which exists between these two laboratories.

APPLICABLE COMPUTER PROGRAMS

water movement	DELFLO	two-dimensional horizontal tidal flow in shallow waters
	DISTRO	non-homogeneous tidal flow in a vertical plane
	ESTFLOW	two-dimensional with a pseudo-analytical three-dimensional option
	NETFLOW	unsteady flow in river networks (one dimensional)
	ODYSSEE	two-dimensional (vertical or horizontal) flow field
	TWOLAY	two-layered system in prismatic channels
water quality	DELQUA	two-dimensional horizontal water quality (coupled to DELFLO)
	DELWAQ	*multi-dimensional water quality model*
morphology	SEDIFLOW	sediment transport/morphology in open channel networks (coupled to NETFLOW)
	WAMOR	two-dimensional sediment transport/morphology (coupled to DELFLO)

Figure 1. Hydraulics modeling programs at DHL.

There are a number of comparisons which can be drawn between the two organizations. First of all, in contrast with LNH, DHL has no finite element program under development. The explanation offered by DHL for concentrating on finite difference rather than finite element methods is that uncertainties in turbulence modeling are far greater than the inaccuracies introduced by failure to accurately specify the boundary conditions. Thus the greater accuracy which is provided by finite element methods in the handling of the boundary conditions is not all that important.

In addition, in contrast with LNH, DHL has no three-dimensional hydraulics simulation programs. This is at least partially due to the fact that its computational facilities are quite limited compared to those of LNH. In fact it has no mainframe computing facilities suitable for computational fluid dynamics calculations but uses, instead, links with a CDC Cyber 175 at the Dutch Energy Center (ECN), the CDC Cyber 205 at the University of Amsterdam, and a Cray at the Shell Research Center. Another reason is that the industrial hydrodynamic activities, which are likely to require such codes, are much more limited at DHL than they are at LNH. This is because DHL unlike LNH has no connection with the power generating industry. LNH's connection, of course, comes from its being a department of Electricité de France, the French electrical power generating monopoly.

My host at DHL was Mr. R. Uittenbogaard. Much of Uittenbogaard's current activities and plans for future research are in the turbulence modeling area. This is a result of a change of direction which has take place at DHL over the past few years. No longer does the construction of flood control barriers and dikes require the large-scale research activities it once did. The period of intense construction of these facilities in the Netherlands is past. Attention is therefore turning to sustaining the navigability and environmental quality of the waterways which have already been constructed. In particular, this means that attention is being given to problems to sedimentation and saline intrusion. Accurate prediction of these phenomena requires accurate turbulence models. Development of accurate turbulence models for the mixing of saline-stratified flows is currently the focus of Uittenbogaard's activities.

Uittenbogaard is a member of a 10-member team funded by the Department of Public Works and Transportation of the Dutch government to carry out experiments which will contribute to improvement in the ability to predict the mixing which occurs in saline-stratified flows. This is a 10-year program which is funded at the rate of approximately $2 million per year.

The experiments will be conducted in the new tidal flume facility which is just now nearing completion. Both

mean and turbulence velocities as well as the position of the saline/ fresh-water interface will be made. At the present time these data do not exist. Measurements will be made with both standard conductivity probes and a new fiber-optic laser probe.

The new laser probe is the result of an instrumentation development program which has lasted several years and has cost more than $100,000. The laser probe is a submersible reference beam anemometer in which only approximately 3 inches of the beam is exposed to the flow. A short optical path length in the flow is necessary to minimize the refraction effects which take place at the interface between the saline and fresh water flows. The advantage of the reference beam over the more familiar (in the United States) Doppler method is that two-component measurements can be more easily made. In addition, a low-power laser can be used, and photo diodes can be used in place of more delicate and expensive photomultiplier tubes.

The new laser probe was designed by Dr. H. Godefroy, who also designed the signal processing equipment. The signal processor is basically a frequency tracker which operates in parallel with a counter in order to overcome the small capture-range restrictions (range in which the signal is regained after a short interruption) of a conventional tracker.

The construction of the second-generation prototype is now nearing completion. It features lenses with antireflection coatings and a somewhat more powerful laser (6 mW instead of 2 mW) in order to enable measurements to be made under poorly seeded conditions. A modification has also been made so that the laser beams cross the flow in a horizontal rather than vertical plane. This allows measurements closer to horizontal (top and bottom) surfaces to be made and also allows for velocity measurements in the vertical plane.

Uittenbogaard and his coworkers are planning a detailed study of the turbulence mechanisms in saline-stratified flows. In such flows, buoyancy effects result in a damping of the vertical component of the turbulence velocity and a resulting decrease of mixing in the vertical plane. This is accompanied by a corresponding increase in mixing in the horizontal plane, and turbulence models must account for this. He feels that the so-called Reynolds stress turbulence model offers the best chance of accurately calculating such flows. He hopes to use the data obtained from Godefroy's laser probe and small catheter-sized microphones to modify the pressure/strain correlation contained in such models. Attention will be focused on the downstream mixing characteristics where the vertical turbulence velocity is nearly zero and the interface has assumed a wavelike structure. Of particular interest here will be the stability of the interface surface and the persistence of any structure produced the manner in which the streams were initially mixed. He also intends to study the intermittent bursts which accompany the mixing process. Eventually, Uittenbogaard hopes to use his work on the Reynolds stress model to improve the performance of the K-ε model, which he views as being more suitable for engineering calculations than the Reynolds stress model because of its greater computational efficiency.

It is clear that the stratified-flow research which is being planned here will make an important contribution in an area where very little data currently exists. I was impressed with the quality of the instrumentation which has been developed. My expectation is that given the funding and resources which have been dedicated to the stratified-flow research work the results are likely to be a definitive study of the subject and may, in fact, shed light on the nature of the mixing phenomenon in other types of flows as well. I believe that the Navy should stay informed about the research at DHL. I plan to visit DHL again in about a year. I will report on the progress at that time.

April 1986

Fluid Mechanics at Delft University of Technology

by Daniel J. Collins. Dr. Collins was the Liaison Scientist for Aeronautics in Europe and the Middle East for the Office of Naval Research's London Branch Office from June 1986 to June 1988.

Although there are three technical universities in the Netherlands, there is only one Aerospace Department. It is located at the Delft University of Technology, which has some 13 departments and [illegible],000 students. The Aerospace Department has a staff of nearly 1[illegible], of whom about 60 are university graduates – 11 professors and about 50 other scientific staff. The department has about 900 students, about 8 percent of whom are foreigners.

The department offers a 4-year program leading to the degree of aerospace engineer. Special fields of study or subject groups, applicable principally in the third and fourth years, include aerodynamics, design and flight

mechanics, stability and control, industrial organization, production and material, structures, and space technology. These subject groups also serve as a basis for research activity.

The facilities of the department are located in relatively modern buildings on the Delft campus. Appropriately enough for an aerospace department, the main building is a 13-story high-rise. The department has close ties with the Netherland's National Aerospace Laboratory (NLR) in that NLR's review committees are directed by professors of the Aerospace Department, and NLR personnel give lectures in the Aerospace Department. The department research committee has two exterior members, one from the Fokker aviation company and one from NLR. My review of the department's research activity includes the following groups:

- Low-speed aerodynamics
- High-speed aerodynamics
- Theoretical aerodynamics
- Aerospace design/flight mechanics
- Stability and control

Low-Speed Aerodynamics

The Low-Speed Aerodynamics Group, with 10 professional staff and 15 students, is directed by Professor J. L. van Ingen. Although this group does some miscellaneous investigations, it has four principal research themes: boundary layers and wake flows; investigation of airfoil sections, wings, and bodies with separated vortex flows; and investigations of airplane configurations. As can be seen from the list, the theoretical and experimental research divides roughly into two classes: one directed at studies related to performance, stability, and control of aircraft, and the other directed at more fundamental aerodynamic research. In addition to a standard low-speed wind tunnel (1.85x1.2x2.6 m) constructed in 1953, the group uses a boundary-layer tunnel (0.251.50 m) to study the effect of heating and noise on boundary layers, and several small wind tunnels. A special-purpose vertical wind tunnel is used for afterbody and laminar boundary-layer research. Data reduction is based on a HP 1000 computer, and there is auxiliary laser equipment for laser-light sheets, and laser Doppler anemometry.

In the area of boundary-layer and wake flows, a recent review of the laboratory's research in low Reynolds number flows has been given by van Ingen and L.M.M. Boermans (1986). This research is directed at the separation region, the laminar part of the bubble, and transition and reattachment. It is shown that a simple bursting criterion is provided by Stratford's limiting pressure distribution for zero skin-friction turbulent boundary layer. The effect of tripping devices to decrease the adverse effect of the bubble on drag is discussed. Comparisons are made of low Reynolds number airfoil designs and tests. The University of Delft has a history of investigation on sailplane airfoils going back to 1980. A new airfoil design with increased performance for the "Standard Class" has recently been tested in the low speed wind tunnel (LSL). Analysis and experiments have also been made on the wing-fuselage combination yielding pressure distributions in the wing-root area. This work is in cooperation with Alexander Schleicher Segelflugzeugbau of Germany (L.M.M. Boermans, G. Waibel, 1987). A powered model of the department's research aircraft, a Beaver DHC-2, has also been tested in the large wind tunnel in order to compare wind tunnel results with flight tests.

High-SpeedAerodynamics.

Diplome engineer W. J. Bannick hosted my visit to facilities of the High Speed Aerodynamics Group. This group is presently awaiting the appointment of a new senior professor. Current staff consists of three professional people and about 15 students. Activity is directed at supersonic flows, transonic flows, and compressible boundary layers. There is a blowdown supersonic wind tunnel (28x27 cm^2), and a blowdown transonic tunnel (15x15 cm^2) in the group. An excellent holographic interferometry setup using a 5-watt argon laser is attached to the supersonic tunnel.

Recent experimental work by Bannick and E.M. Houtman on transonic flows over a delta wing at high angles of attack was reported at the conference on the US/European Vortex (Transonic) Experiment in October 1986 at Stockholm, Sweden. For this study, measurements were made on a cropped delta wing with a swept angle of 65 degrees at angles of attack of 10, 15, and 20 degrees at Mach 0.85. A five-hole directional probe was used to explore the external flow field. A complex transonic flow pattern was revealed in the shock wave structure. The measurements also revealed that a nonconical shock wave between the primary vortex and the wing surface interferes strongly with the vortex system.

Further indicating the nature of the work this group does are two 1986 internal reports, which considered, respectively, an integral equation approach to plane transonic flow, and a simple method to calculate the pressure distribution on a flat delta wing with supersonic leading edges.

Theoretical Aerodynamics

The theoretical Aerodynamics group, directed by Professor J. A. Steketee, has a professional staff of five and 12 students. They cover a variety of activities involving incompressible flows, gas dynamics, magnetogas dynamics, and elasticity theory of dislocations. The emphasis is on analytical methods and not on numerical approaches. Optimal supersonic wing theory is one area

of specialty as well as unsteady rectilinear motion. Recent work by Dr. A.J.M. Jansen has been on fluid motions generated by the injection of an electric current. Dr. H.J. Bos has a recent paper on optimum supersonic wings with subsonic leading edges. Steketee has some work on the application of the Stanyukovich transformation to unsteady rectilinear motion.

Aerospace Design/Flight Mechanics

The Aerospace Design/Flight Mechanics Group, which has 26 students, is directed by Professor H. Wittenberg, who is also dean of the faculty. The research interests of the group are divided into two sections involving airplane design/flight mechanics and space technology.

Airplane Design/Flight Mechanics. In this area of investigation, the group develops analytic and numerical methods for preliminary design of aircraft. Their preliminary design program, called ADAS (Bil, 1986), has recently been implemented in a substantial interfaculty computer aided design (CAD) laboratory, which consists at present of 10 Sun workstations with numerous PC's, connected by ethernet to a central laboratory which has 20 Apollo workstations. The CAD laboratory is large and well equipped both with hardware and software, and is being continually augmented at the rate, currently, of four Sun workstations a year. The aerospace engineering faculty is active in the application of geometric modeling (MEDUSA), finite element method (GIFTS), and structural optimization (FEM).

The Solid Fuel Combustion Chamber (SFCC) research project, a joint project with the Prins Maurits Laboratory of the Organization for Applied Scientific Research (TNO), involves six of the group's professional staff. The purpose of the project is to develop better understanding of SFCC's. Several computer codes have been created to further this purpose, among them COPPEF, which models steady two-dimensional turbulent flows with or without a sudden expansion, and KINETIC, a code for ignition and combustion of stagnant gas mixtures with finite chemistry (Korting et al., 1986). Theoretical calculations are being compared with experimental measurements. The application of laser Doppler anemometry to measurements in a SFCC is also being studied, and an ultrasonic-pulse technique is being used to measure local instantaneous regression rates.

Space Technology. The space technology section is concerned with orbit prediction and orbit determination of earth satellites and spacecraft system analysis. Contracting is from the European Space Agency (ESA). Research has included studies of laser positioning systems, use of satellite-borne radar altimeters in oceanographic research, and satellite orbit perturbations due to tidal forces.

Stability and Control

The Stability and Control Group, with 11 professional people and 43 students, is directed by Professor O.H. Gerlach, who has been active in modeling human pilots. Research activities are oriented into six areas – flight measurements, modeling of human pilots, stability and control, flight simulation, digital flight control, spacecraft dynamics, and avionics. Connected with these activities are three laboratories:

- The Flight Simulation Laboratory, started in 1955 and directed by M. Baarspul, is a sophisticated flight simulator in which I had the opportunity of crashing a 707 aircraft. This type of simulator is typically found in aircraft manufacturing companies in the US. A real-time digital computer system drives the simulator with a realistic visual display. The motion system generates specific forces and accelerations of a high-fidelity 6-degree-of-freedom aircraft. The simulator is used in flight-crew training, research on the man/machine interface, aircraft cockpit display design and development, and certification and accident investigations. Future research with the facility will concern rotorcraft simulation, flexibility of large airplanes, and microprocessor architectures (Baarspul, 1986). Some work on sidestick controllers is also being done in the laboratory by R. Hosman.
- The Satellite Control Laboratory, directed by Mr. P. Ph. van den Broek, has an interesting if somewhat dated satellite simulator which can be used for testing different attitude control strategies. Computer simulation of spacecraft attitude controllers is also part of the laboratory's work.
- The Flight Test Laboratory, directed by Dr. J. A. Mulder, has had an active program on the estimation of aerodynamic derivatives from dynamic maneuvers with earlier work going back to at least 1970. At the Navy Test Pilot School parameter identification through in-flight test is a standard procedure. Typically parameter identification is accomplished by maximum likelihood estimates based on extended Kalmin filters. Mulder (1986) has reported on a two-step method for analysis of flight test measurements in which the first step is a nonlinear state reconstruction problem, called flight path reconstruction. The second step is a parameter estimation problem which is linear-in-the-parameter. This method has been flight tested on the department's Beaver DHC-2. New emphasis for this section is on flight control using zero error gyros and accelerators. The concept is interesting but so far there are no publications on this new activity.

Under the headings of "digital control" and "stability and control" is some work connected to the Cessna Citation 500, where a series of restricted studies have been

made of a prior control systems. Further work is concerned with robust controllers and adaptive controllers, but is only available in Dutch. Finally, the group is working on a project connected with the development of central control software for the department based on the CASPAR system.

Conclusions

The University of Delft Aerospace Department is involved in an interesting mixture of activities in the US that would be scattered among industry, academia and government laboratories. The high-quality simulator laboratory would normally be found at a company like Boeing (with the work being initiated by NASA – as in its advanced cockpit concepts project). The wind tunnel facilities, although excellent for a university, fall short of what one would find at NASA Ames or indeed the Netherland's NLR. I had the impression that the department in some sense is carrying a relatively heavy burden of work in its facilities. These facilities do permit the direct comparison of theoretical predictions and experimental measurements, as indicated by my comments above, and such comparisons are essential for good aerodynamic research. Some basic research is accomplished in the department but there is a heavy emphasis on applications. Subsonic civilian aircraft are important in the research due, perhaps, to the influence of the Fokker company.

I believe the Aerospace Department plays an essential role in the university environment in the aerospace industry for the Netherlands. Many of the engineers at NLR were educated at Delft. It is clear to me that the Delft Aerospace Department is the Netherland's center of excellence in aeronautics.

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12/29/87

INFORMATION TECHNOLOGIES

The Dutch PTT Laboratories' Work in Information Technologies

by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

Introduction

The Dutch Postal, Telephone and Telegraph Administration (PTT) Laboratories, established in 1946 in The Hague, were originally known as the Central Laboratories. They were renamed in 1955 as the Dr. Neher Laboratories (DNL), after the founder.

The emphasis at DNL is on targeted developments to meet the present and future needs of the Dutch PTT. Although DNL works primarily for the PTT, some work is done for others where there is no conflict of interest.

The activities of DNL include seven main fields:

- Communications
- Research and systems
- Transmission and coding
- Applied mathematics and signal processing
- Mail systems research
- Radio communications and electromagnetic compatibility
- Physics and chemistry
- Applied computer science.

DNL has an advanced computer network including a VMS control system on a clustered VAX 8800/8700 computer system, a central computer system with remote computers, and work stations. An Ethernet local area network (LAN) and a digital PABX provide the data communications system. There is also a microprocessor development system with workstations from Philips, Hew-

litt-Packard, and SUN. Also, personal computers have been introduced on a large scale with the objective of supplying each employee with his own terminal. The seven main fields of research and development are briefly described in the following paragraphs.

Communications Research (CR) and Systems Section

The activities the researchers in this section specifically support present and future telecommunications networks and services of the PTT. Their interests are methods, techniques, and standardization.

Concerning networks, the narrowband Integrated Services Digital Networks (ISDN) will be able to provide a large number of services, but with broadband ISDN the options will be much greater. The vastly increased bit ratios will lead to the introduction of new applications. In order for networks to be open to these new applications flexibility must be built into the networks. Standardization and harmonization are needed. This group's objective is to make sure that specifications are drafted and an implementation strategy is developed to achieve this flexibility. The interests of the PTT in the definition of interfaces and control procedures and in the development of migration strategies must be protected. The group must also carry out research in the Open Systems Intercommunication (OSI) reference model for telecommunications networks. In the long term, preparation must be made for broadband ISDN which entails new switching principles, network architectures, subscriber interfaces, control, and network services. Much of this work is carried out under the European Community's program for R&D in advanced communication technologies (RACE). In the near-term narrowband ISDN, the main areas of work are in control, business and mobile telecommunications, and network services. In this, cooperation with RACE and with the international standard bodies the Comité Consultatif International Télégraphique et Téléphonique (CCITT) and the Comité Européene Postes et Télécommunication (CEPT) are essential.

In order for ISDN to be effective, the individual facilities, such as alpha-numeric mode traffic and Voice Mail, must be available to the user in a uniform way. Procedures, dialing information, directories, formats, and accounting should be the same. The provision of these different forms of service – into a single, integrated service from the subscriber's viewpoint – requires multiple mapping at the transport and application levels. This demands an infrastructure at the application level, and the communications research section is currently investigating an integrated approach. The principle fields to consider are man/machine interaction, the development of services, and the integration of services.

The protocols between terminal and host computer and the user friendliness of the service provided are important considerations. The conceptual aspects such as the management, charging, presentation, central access, division of function and relation between subscriber and service are being investigated, and should lead to the handling of different types of service in a uniform way. The investigation will ensure that new developments fit in with the desired concept and will provide a basis for the consultancy needed in this field.

An architecture in which a fully integrated services package is available to the subscribers requires a thorough study of the functional structure of the concept. The purpose is to combine the service-independent resources in the best possible technical way, and in which the migration path is carefully chosen. CR will devote attention to an intelligent gateway in the infrastructure, as the first step on the migration path. Such an integration of access at the application level will enable the subscriber to gain access to services which are at present separate. The intelligent gateway will provide protocol conversions, uniform procedures, and authentication.

CR participates in the work of international standards bodies, including CCITT, CEPT, and ISO.

The international standardization work will be closely followed to evaluate consequences for the Dutch PTT, to give guidance for developments within the Netherlands, and to defend the PTT's interests and policies in the international forum.

Conformance testing to determine conformance of a protocol implementation to the specification made by CCITT or ISO is essential to the functioning of the communications structure. CR specifies and develops the test environments and test suites for conformance tests of networks and services. For example, CR is now working on the conformance testing of the C7 signalling protocol in development of specifications for the testing of the D channel protocol, and on the development of the test suites for message handling services. This work is done in cooperation with the Applied Computer Science Section, which is responsible of the development of the conformance testing method. CR is mainly concerned with its practical application.

Transmission and Coding (TC) Section

Current transmission technology, based on direct detection transmission systems, allows less than one millionth of the carrying capacity of the cables to be used. The Gbit/s systems now being developed are a variation of the direct detection transmission systems. A promising possibility for exploiting the full capacity of fiber cables is the application of coherent techniques. TC will be investigating this research field in the years ahead, working

closely with the Physics and Chemistry Section. It is likely that coherent techniques will be applied to operational systems within a few years.

To assure transmission quality, standards used in transmission have to be checked as efficiently as possible, which requires automated measuring systems and specialized personnel. Video transmission systems with speeds to 140 MBit/s, are expected on the market within the next few years. Further research is needed to achieve optimum video quality for these systems. This is also true for the broadcasting network.

The PTT needs a more detailed understanding of fault behavior in digital transmission systems. TC is developing a measuring and recording system, which is now operational. A special appliance-testing system for the telephone has been developed and is now in service with the PTT. The introduction of digital mobile communications will have consequences for transmission quality. These consequences will be investigated and influenced by TC.

The research and development required for local area networks (LAN's) and integrated networks (broadband ISDN) are areas of interest and importance. Functions such as multiplexing demultiplexing, control, and protocols are being investigated. TC is also doing the necessary research for the options in creating a flexible infrastructure of flexible, digital, leased data circuits of various speeds to meet the requirements of a growing market need.

In speech and music coding there is a growing requirement for the efficient use of transmission systems in areas such as mobile communication and the use of 64 bit/s channels. Microelectronics is constantly opening up new possibilities. TC is cooperating with European programs in this field. Standards for music coding have been established, and new coding techniques enable the bit rates to be reduced to 128 kbit/s.

TC has developed a highly successful 2 Mbit/s video conference circuit and a codec with a speed of nx384 kbit/s. They have also begun work on a videophone to operate on the 64 kbit/s infrastructure.

First steps have been taken in TC in high-definition TV (HDTV), which can supply the moving force behind the growth of broadband ISDN technology and prepare for various new PTT services. International cooperation is needed since HDTV involves heavy investment for its development.

TC is involved in collaborative projects with both ESPRIT and RACE.

Applied Mathematics and Signal Processing Section

The applied mathematics people are mainly concerned with operations research and cryptology. The signal processing people concentrate on automatic reading, speech analysis and synthesis, and multiprocessor systems.

To guarantee user friendly telecommunications services the PTT must have a top-quality telecommunications infrastructure. The emphasis of this group is on the design of the infrastructure, which implies weighing a range of technical, economic, and managerial factors. A study is being made of the strategic development of telecommunications networks, and proposals are generated for possible implementation. For this purpose mathematical techniques such as those for operations research and econometrics are used. Methods and algorithms are developed to determine network structures, routing, dimensioning, traffic control and measurement, and the evaluation of networks. Systems are designed and developed for use in planning telecommunications networks and services. An example is the multipurpose system for networks, a general-purpose model and method bank used in the design of telecommunications networks. The group cooperates in the European Cooperation on Science and Technology (COST) and RACE programs.

There is a growing market for cryptographic systems. While the users of the PTT's telecommunications infrastructure expect a secure network, they also require information security as a specific service. Encryption methods and cryptographic protocols are essential as a means of making information and information flows secure. Cryptographic systems are developed for a variety of security purposes including identification, data integrity, secrecy, and privacy. In-house cryptographic research is performed by the Signal Processing Section with the aim of maintaining, extending, and disseminating its knowledge. They advise on and assess cryptographic systems in use by the PTT or which are commercially available. They design building blocks for services and application in the telecommunications infrastructure. They also design cryptographic systems as peripherals and assist in the design of key management systems. Some examples are the TOBIAS system for access/monitor/information/ alarm system used by the PTT. The system is used to monitor movement in and out of buildings. The section also contributed to the security system used by the PTT's mobile radio telecommunications network.

An automatic reading system for hand-written numbers on grid documents, involving a man-machine combination in which the machine confirms human interpretation, is in operation with the Netherlands Post Bank. The hardware developed for the Post Bank has been in service since the 1970's although it has since been improved.

The Applied Mathematics and Signal Processing Section carries out research into the application of speech processing technology, and puts its findings into practice where possible and desirable. They were involved in the

development of the VOX-600 – the PTT's telephone answering machine which features a built-in speech module. Another product is the Auditor Automatic Information Dialogue System, a collaborative project with Philips. The section is also active in speech analysis and synthesis. The hope is that this work will lead to a speech recognition and synthesis system.

Mail Systems Research (MSR) Section

The work of this section centers on research in automation equipment for mail sorting and document processing, and on equipment for registration, analysis, and process control. The section has expertise in mechanical engineering, electrical engineering, information technology, physics, and industrial design.

MSR is endeavoring to achieve an optimum combination of man and machine for data and physical materials input systems. Besides automatic reading and indexing equipment, MSR has developed a manual indexing device which is already on the market. A prototype of a second generation of this device has been built; it features the latest in ergonomics and engineering.

A number of subsystems are involved in mail sorting and data collection systems. Not all of the subsystems are exclusively electromechanical. Included are:

- Stackers, which stack documents into piles
- Feeders, which remove individual documents of mail items from a pile
- Diverters
- Light emitter/receiver combinations for the detection of mail items
- Aligning devices
- Machine codes, with reference to information content
- Printers for printing codes
- Automatic reading systems for code detection
- Control and signal systems
- Data acquisition systems.

The latter two subsystems are based on pattern recognition technology.

The importance of flexible automation to allow partial processes to interface and combine with each other is of strategic importance to the PTT. At MSR a broadly based robotics program is in operation for use in flexible automation. It provides experience in complex control systems, expert systems, sensors, vision systems, and standardization of data communications in production environments. Stock keeping, for example, can benefit from automatic stocking and destocking, directly linked to logistic control systems.

The construction section of MSR provides prototypes of products such as special antennae for satellite projects, prototype printed circuit boards, and special ergonomic furniture.

Radio Communications and Electromagnetic Comparability (RE) Section

This section conducts research into radio communications and electromagnetic compatibility. Special attention is given to radio propagation, radio systems research, and electromagnetic compatibility. The PTT employs microwave links and satellite communication for a number of its services. Interference between services using the same frequency band may occur due to dispersion of radio waves due to raindrops or by exceptional atmospheric conditions. The consequences of these effects can be avoided through proper design. RE participates in the development of planning tools such as prediction modules for interference phenomena. The PTT then uses these tools to plan services based on microwave links and satellite communications to protect them from interference.

The main issues of concern in radio systems, microwave links, and satellite communication are:

- The consequences of propagation effects on the transmission properties of digital microwave links and ways of combatting those effects
- The interference sensitivity of modulation methods for microwave links and satellite communication and the effects of frequency sharing
- Aspects of coding, access, and encryption employed for radio links used for business
- The use of non-geostationary satellites
- The testing of electronically controlled antenna beams for the reduction of multipath fading in microwave links
- Research into the feasibility of special frequency bands for specific radio application.

In 1989, the Olympus satellite will be launched under the auspices of the European Space Agency (ESA). It has been designed for, among other things, the study of transmission and propagation in the 12-, 20-, and 30-GHz bands. RE is a member of the Olympus Propagation Experimenters. Based on the information gained from propagation measurements with Olympus, tools will be developed for the prediction of effects like attenuation and cross polarization decoupling on the satellite path. These tools are needed for the PTT's planning of new services.

RE is also taking part in the CODE experiment, which involves a star-shaped network based on very small and simple earth stations (VSATS). This will lead to considerable knowledge and experience in microwave technology, antenna measuring techniques, and digital signal processing.

Mobile communications is a rapidly growing field of activity for the PTT – e.g., the car telephone. Work is in progress at the European level on a Pan-European mobile telecommunications system known as GSM. RE

is developing propagation models, omit planning tools and prototypes of mobile radio systems. Other sections of DNL involved in this are communications research and systems, transmissions and coding, and applied mathematics and signal processing.

A project called "New Mobile Systems" is underway, on the design of a large-scale mobile communications system in the 1800-MHz band. RE is also examining the field of mobile communications by satellite.

In electromagnetic compatibility RE is working to develop tools which will enable the PTT to keep the electromagnetic interference of telecommunications equipment within specified limits. Another important project is the protection of information from being tapped. Mechanisms are being explored and measuring methods established which will result in suitable electromagnetic compatibility specifications.

RE will also devote much attention to new technologies including hybrid circuits, monolithic (microwave) integrated circuits, and digital signal processors.

Physics and Chemistry Section

The five main fields of work in this section are: optical fiber and optical fiber cables, coherent optical communication systems, integrated optics, the quality of components, and chemical research.

The physical research into optical fibers concerns the development of measurement set-ups for measuring signal attenuation, cut-off wavelength, mode field diameter, dispersion, and refractive index profiles of optical fibers. Practical applications are investigated including splicing, the stripping of coatings, and the comparability of different makers of fibers.

Theoretical models and experiments are used to help understand the degradation mechanisms of optical fibers. Installation techniques and the long-term effect of environment on cables and fibers are subjects of concern.

Current optical communications systems use only a small part of the capacity of optical fibers. Even with wavelength multiplexing no more than a few tens of GHz of the total bandwidth of about 30,000 GHz are actually used. Coherent optical communication systems permit much more efficient use of this bandwidth. They involve wavelength multiplexing which is several hundreds of times more compact and offers improved sensitivity by 10 to 20 dB. However, more research into components and other aspects of systems is required before coherent optical techniques can be applied. This section is conducting research into lasers, modulators, polarization-maintaining fibers, active polarization control systems, and coherent optical receivers. The knowledge gained is being applied in a project, run jointly with the transmission and coding section, to develop a coherent system which will permit an entire multichannel cable television signal to be transmitted in analogue form along a single optical fiber.

Integrated optics is the branch of technology concerned with the development of optical chips, miniature optical circuits on a flat surface. Light is conducted by means of total reflection along the walls of the waveguide, as in an optical fiber. At the current level of this technology the optical chip can contain just one optical component, an optical switch, for example. Various components are needed including active components like light sources, detectors, switches, and modulators, and passive components like splitters, forks, star and directional couplers, and wavelength multiplexers. Good results have been obtained in this section using diffused waveguides in glass substrates. For active components the electro-optical effect in lithium niobate, polymers, and indium phosphides are used. For example, lithium niobate technology is being used to develop phase modulators and polarization controllers. The use of electro-optical polymers for switches is a new and promising field of research. This section's researchers are participating in the RACE program in an investigation of this field.

The Physics and Chemistry Section is studying the properties of components and the failure mechanism which cause them to malfunction. Measuring and test methods are being developed. Other subjects under study include quality assurance, electrostatic discharges and statistics. Research is also being carried out here in integrated circuits, IC packaging, surface mount technology, optical fiber, and other connectors, relays and semiconductor lasers.

Applied Computer Science Section

The Applied Computer Science Section develops information systems and performs research into new programing methods and techniques for the PTT. The section is doing research into formal languages based on mathematical principles, which do not have the disadvantages of natural languages. Based on these techniques, specification can be processed by machines. Automatic checks and the automatic generation of working prototypes are possible.

The PTT develops systems for its own use and undertakes maintenance contracts for other companies' systems. It also makes up specifications which are used as a basis for contracts with suppliers. In this work the application of formal specifications is of great importance. The section also participants in the standardization of formal specification languages within CCITT and ISO. Its research is partially carried out in the ESPRIT and RACE programs of the EC. As an example the applied Computer Science section is involved in a joint study within RACE of the applications of formal specifications tech-

niques in the planned European Broadband Communication Network (IBCN).

Adherence to software engineering principles can result in higher productivity and better quality in the development of software. The PTT participates in software engineering projects to better carry out the definition, development, and adaptation of software products. An application field is in the software development in the PTT's automation branches and laboratories.

The PTT's research into the development of expert systems is done in the Artificial Intelligence Center of the applied computer science section. The hardware in use includes a VAX-UNIX computer, SUN workstations, and personal computers. The software includes the AI languages Lisp, Prolog and Popll, expert system shells for personal computers, and ART, an advanced AI development environment used on SUN workstations.

The work in the security area centers on cryptographic methods of transmitting and storing large quantities of data. The emphasis is on efficiency and speed, for encryption of speech, video, and data. Research is also being done into improved methods of personal identification through passwords, smart cards, speech recognition or biometric data. The section also carries out work in security auditing, which involves research into the extent to which a program, a systems or a network is secure. A study is made of the hardware, software, organizational framework, and physical access. Risk analysis is used to assess the security measures which are in force, and to determine whether additional measures should be taken.

Conformance testing, having to do with the development of methods and tools for testing telecommunications protocols, is of strategic importance for the PTT. The PTT is a major consumer of protocol implementations and it has to ensure that its customers can communicate with each other even when they are using equipment supplied by a third party. The Applied Computer Science Section is developing methods of systematic and automatic protocol testing, which has previously been performed manually.

4/29/88

MATERIAL SCIENCES

Tribology Research at the Metal Research Institute of TNO

by Irwin L. Singer. (This article was originally published in November 1986 [ESN 40-11/12].)
Dr. Singer is head of the Tribology Section in the Chemistry Division at NRL. He was on sabbatical leave at the Metallurgy Department of Cambridge University, England when he wrote this article.

If you ask A.W.J. de Gee "How wear resistant is steel?" he'll no doubt say, "That depends." And he's not trying to be divisive. Over the past 15 to 20 years, he and many tribologists around the world have come to appreciate that wear is not a material property; rather, it is a property of a system whose components, environments, and interactions contribute to bring about (or protect against) failure of materials in moving contact. Nonetheless, de Gee's responsibility at the Metal Research Institute of the Netherlands TNO, in Apeldoorn, is to select materials – solids or liquids – for tribological applications. My aim in visiting de Gee was to learn the methods he is using to evaluate the tribological behavior of a variety of practical materials, ranging from lubricant additives and surface treatments for steels to nonmetallics like polymers, and the system's parameters which are most likely to control the friction and wear processes.

TNO – The Netherlands Organization for Applied Scientific Research – is a nonprofit research and development organization established in 1930. (For detailed information on TNO's organization, policy, and funding see *ESN* 38-8:438-440 [1984].) Its 5000 staff members perform research ranging from industrial projects for individual companies to basic research financed by the Dutch government. TNO has two groups working in tribology – the study of friction, wear, and lubrication. One group in Delft concentrates on mechanical design aspects of bearings, gears, and related devices. The other group, in the Metal Research Institute at Apeldoorn, specializes in materials problems, with particular emphasis on the tribological interactions between materials, lubricants, and environments.

Philosophy

Tribology research at Apeldoorn has always emphasized the role of tribometry in the selection of materials for tribological applications. "We always try to learn as much

as possible about the function of a machine's triboelement, whether it be a cam, gear, bearing, etc... Only then do we select, or if necessary, develop a tribometer adapted to the function of the machine." De Gee, therefore, is not interested in standardized wear testers. "A tribometer (i.e., a laboratory-scale testing device) should be chosen to simulate the contact conditions and type of motion that would be found in practice." He is, however, interested in standardizing wear testing methods, and the Metal Research Institute sells a multipurpose tribometer designed to control the most important variables applicable to a particular test.

From years of experience, de Gee and his colleagues A. Begelinger and G. Salomon (now deceased) came to regard three variables of the tribosystem as most in need of controlling and understanding: load, speed, and temperature. These variables play an important role in the lubricated sliding wear behavior of metals whose contact zone concentrates the stresses to a point or a line. The investigations that have led to present-day understanding of the failure mechanisms in lubricated wear processes began over 15 years ago as a multinational cooperation established under the banner of the *International Research Group (IRG) on Wear of Engineering Materials.* From this effort came, amongst other concepts, the systems approach to analyzing problems in tribology and the transition diagrams to be discussed below.

Load-Carrying Capacities of Concentrated Contacts in Lubricated Sliding

The Transition Diagram. The wear behavior of metals in concentrated (nonconforming) contact under lubricated sliding conditions can be mapped out by a transition diagram, which plots the normal force F_N vs. sliding speed at a given oil bath temperature. A typical transition diagram, obtained for hardened steels in the ball vs. cylinder contact geometry, is illustrated schematically in Figure 1. One sees three regions of different wear behavior, separated by two "transition" curves. In region I, wear is usually invisible to the naked eye on the cylindrical surface and only a small contact spot can be seen on the ball. In region II, a visible oxide layer forms on the cylinder and a correspondingly large spot is worn on the ball. In region III, the wear scars and debris layers on both surfaces are huge by comparison with regions I and II. It is believed that the specimens run virtually unlubricated, despite being fully submerged in the lubricant. Although discussed here for the ball vs. cylinder contact, the transition diagram has been found to apply in most common geometries (e.g., 4-ball, crossed cylinders, ball vs. flat) used to study the wear of concentrated contacts.

Regions I, II, and III can also be distinguished by friction vs. time curves, which also correlate with the wear behavior. In region I, the friction coefficient briefly jumps to 0.3, then within a second, drops to a steady-state value between 0.05 and 0.1. Very high wear rates occur during the brief high-friction period, followed by much lower and steadily decreasing wear rates, often resulting in acceptably low wear. In region II, the friction coefficient jumps to 0.3, remains there for 5 to 10 seconds, then falls to a steady-state value near 0.1. This initial friction plateau results in a factor of about 10 or so greater wear than in the initial wear in region I. Subsequent wear rates are also low and, as in region I, eventually fall to zero. In region III, the friction coefficient jumps to 0.4 and remains there throughout the test; wear is severe, the wear rate being high and constant. Hence, friction behavior not only affects wear, but also provides an easily identifiable signature for the three wear regions.

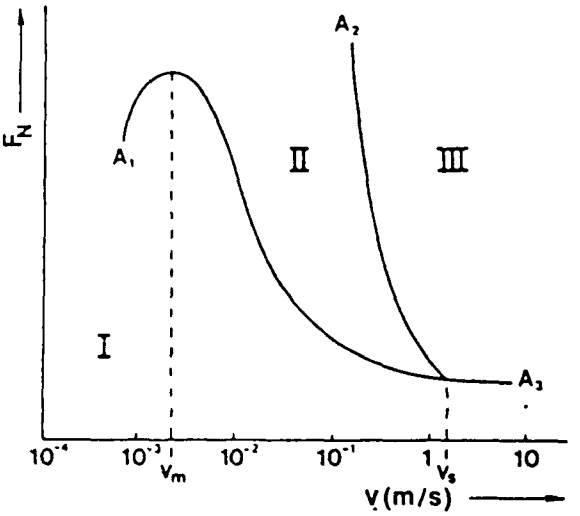

Figure 1. The transition diagram for ball-cylinder contacts at constant oil bath temperature (schematic): I, regime of (partial) elastohydrodynamic (EHD) lubrication; II, regime of boundary lub rication; III, regime of virtually unlubricated contact ("scuffing regime").

The main factors which influence the load carrying capacity (i.e., the location of the various transition curves) have been identified. The lower transition curve (A_1A_3) decreases as the ini tial surface roughness increases, and increases as the lubricant viscosity increases. The oxygen content and the chemistry of the lubricant are also important, whereas the metallurgical nature of the surface is of secondary importance. The upper transition curve (A_2A_3) depends mainly on the metallurgy of the surfaces and the chemistry of the lubricant. These transitions are usually quite abrupt, occurring with load changes of several Newtons.

Failure mechanisms. A model which explains these experimental results has been examined and developed by de Gee, Begelinger, and Salomon. They assume that in region I a condition of partial elastohydrodynamic lubrication prevails. Friction and wear behavior are attributed to initial asperity (i.e., surface high point) wear,

followed by oxidation or other chemical reactions, giving way to virtually no wear as the earlier mild wear processes tend to drive the two surfaces into conformity. The "no wear" condition is obtained when elastohydrodynamic (EHD) conditions are established. (Elastohydrodynamic lubrication indicates that the fluid behaves like an elastic solid capable of transmitting pressure and carrying loads.) The rise in the lower transition curve at low speeds can be explained by the hydrodynamic wedge effect, known to increase the load carrying capacity. The transition to regions II and III results from collapse of liquid film lubrication. At speeds above V_m, frictional heating of the fluid in the contact zone reduces the viscosity and therefore the load carrying capacity of the EHD film.

If collapse of the EHD film occurs at $V < V_x$, then the two surfaces come into contact, resulting in high friction and sustained mild wear. Region II may thus be identified as boundary lubrication. Gradually, the load bearing area increases, EHD conditions are reestablished and the wear rate goes to zero. If collapse of the EHD film occurs at $V > V_s$, the temperature at the junction rises above the critical temperature at which boundary lubrication fails, and scuffing (region III) ensues. The transition from region II to region III at low speeds is also due to failure of boundary lubrication, but not because of lubricant failure. Rather, the transition to scuffing is dependent on the metallurgical stability of the surfaces during the initially high friction contact, where temperatures can easily reach 400 to 500°C. These temperature-sensitive transitions have been studied both experimentally and theoretically (Blok-Archard models), and are in good agreement with the behavior of the transition diagram.

Application to Lubricants. Transition diagrams were obtained for a purified oil containing five additives known to improve the wear performance of steels. Two of the additives, TCP and stearic acid, significantly increased the first transition curve, while two other additives, DBDS and ZDDP, greatly increased the second transition curve. (Interestingly, TCP actually lowered the "scuffing" transition.) TCP and stearic acid promoted partial EHD films at high loads by reducing friction-generated heating of the films, while DBDS and ZDDP resisted scuffing by reducing friction-generated degradation of the surfaces. These tests also illustrate the folly of attempting to establish the intrinsic wear-abating behavior of additives without reference to specific load, speed, and temperature conditions. For example, at moderate loads, TCP promoted EHD lubrication but DBDS did not; hence, TCP would be considered a "good" additive. By contrast, at twice the load, TCP-doped lubricants led to scuffing whereas DBDS-doped lubricants produced only mild wear.

Application to Coatings. TiN- and TiC-coated steel balls had significantly higher load carrying capacity than uncoated steels. Interestingly, comparisons of coated vs. coated and coated vs. uncoated curves showed that one coated surface provides more protection than two coated surfaces. Surface treatments may also reduce wear, as was the case of salt-bath nitriding of steel, which eliminated scuffing in regime III.

In summary, transition diagrams identify the loads dividing fluid film lubrication from stable (boundary lubrication) or unstable (scuffing) wear conditions as a function of speed and oil temperature. As illustrated in the above two examples, these diagrams make it possible to characterize novel materials, surface treatments, and lubricants for application in which concentrated contacts prevail. And, of great importance at TNO, they have been shown to predict reasonably well the wear behavior of many tribocomponents such as cams and tappets, worm gears, etc. operating in unidirectional sliding.

Friction and Wear Behavior of Polymeric Materials

A second example where the systems approach is leading to simple, reliable tribotesting is for polymeric materials. It was recognized early on that polymers, even more so than metals, degrade because of heat buildup at the frictional interface. Polymers, in fact, pose special materials problems in that their thermomechanical behavior is often more closely related to the manufacturing history than to the chemical formula. Therefore, there was a great need for a quick and reliable test method capable of predicting the friction and wear behavior of materials at any speed or velocity. In the 1970's, TNO developed a tribotest method that was capable of explaining what happens to brake lining materials (polymeric composites) brought in contact with mating metal surfaces at a fixed temperature. Isothermal conditions during friction and wear measurements were assured by making periodic contact lasting only seconds. Unfortunately, the tests were very time consuming, so they could not be relied on to provide data for all temperatures; moreover, they could not answer the practical question of how a given material behaves after repeated thermal cycling under stress.

Recently an improved test method has been devised by de Gee and his colleagues. They call it a pseudoisothermal friction and wear test. Friction coefficient and pin wear measurements are recorded during (relatively) low-speed sliding while the temperature is increased from near room temperature to some maximum (e.g., service limit) temperature. Friction vs. temperature and wear vs. temperature curves, so obtained, give signatures of the friction and wear behavior of the materials. These curves, for selected materials, have been shown to contain all the information needed to predict the friction vs. temperature behavior at higher sliding velocities or the friction vs. velocity behavior at higher temperatures.

The testing, however, is neither simple nor routine. A tribotester had to be engineered to be sensitive to the viscoelastic properties of polymers. Polymers, more so than metals or ceramics, are sensitive to vibrations and sample eccentricity. Also, pin wear measurements required special calibration procedures in order to account for the thermal expansion of the viscoelastic pin under stress. The difference between the pin "wear" measurements in static (V = 0) and dynamic (at test speed) pseudoisothermal tests gave the true pin wear.

This method was first demonstrated on a series of friction materials, brake liners (Honselaar and de Gee, 1985). The curves yielded a 'fingerprint' for each of the brake liners, characteristic of their composition and structure, which could be used for identification purposes and acceptance testing. In evaluating the performance of brake liners, it is also necessary to characterize the friction and wear behavior of materials subjected to repeated contact at high service temperatures. Curves obtained after repeated runs showed great variability, depending, in particular, on the maximum temperature. However, analysis of these curves and of the material transferred to the metal counterface gave a fairly accurate picture of the in-service performance of brake liner materials.

More recent studies have confirmed that the pseudoisothermal test method is also a fast and reliable method for assessing the friction and wear vs. temperature behavior of antifriction polymers, such as polyimides, used in high-temperature applications (Uppsala University, 1986). In these studies, the pseudoisothermal curves obtained at slow sliding speeds (V = 0.01 m/s) gave the same friction vs. temperature curves measured at higher sliding speeds (V = 0.3 m/s), after adjusting for a velocity-dependent interfacial temperature. This temperature averaged about 30°C higher than the value measured by a thermocouple buried within a millimeter of the polymer interface, with variations from 10 to 80°C, depending on the amount of film transferred during sliding. As happened in the IRG transition diagram studies, a great number of tests will be needed to decide on the range of applicability of the pseudoisothermal test method for polymeric materials.

Summary and Conclusions

The value of the mix of applied and basic research is apparent in the work at TNO. Much of the early data that led to the transition diagram model was obtained studying real-world industrial problems by trial and error, relying on feedback from suppliers of lubricants or alloys. With increasing confidence came more detailed investigations of the failure mechanisms of thin lubricating thin films. In the 1970's, when more than half of the group's funding came from the government with "no stings attached," there was ample incentive to tackle these fundamental issues. Today, with government support at the 10 percent level and industrial support at 70 percent, quick answers often override sustained scientific efforts.

The changing funding pattern has also brought on new roles for de Gee and the tribology group. In the 1970's, with a staff of 22 engineers and scientists, the group could and did provide the know-how, equipment, and manpower to assist industrial firms like Phillips build their own tribology groups. Today, with many more tribologists competing for fewer dollars, TNO's four remaining tribologists are hard pressed to carry on applied and basic research by themselves at previous levels. It is de Gee's hope, however, that future applied tribology research in the Netherlands will be carried out by a consortium made up of TNO and the Dutch technical universities (where he teaches part time).

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8/18/86

MATHEMATICS

Nonlinear Diffusion at Leiden

by Charles J. Holland. (This article was originally published in June 1985 [ESN 39-6].) Dr. Holland was the Liaison Scientist for Applied Mathematics/Computational Science in Europe and the Middle East for the Office of Naval Research's London Branch Office from December 1984 to December 1985.

Professor L.A. Peletier heads a small group of researchers at the University of Leiden, the Netherlands, doing important work on the modeling and analysis of nonlinear diffusion-reaction processes. An essential fea-

ture of these problems is that the diffusion coefficient may vanish over a range of parameter values. This degeneracy allows for a more realistic finite speed of propagation or dispersal, but at the same time requires a more sophisticated mathematical analysis using appropriate weak formulations of the partial differential equations modeling the phenomena.

In this article, I will give a brief physical motivation for studying these problems and then discuss in some detail two particular classes of phenomena that have been investigated recently by the Leiden researchers.

Background

Until recently, much of the modeling of physical diffusion processes and the associated mathematical analysis has been based on a continuum-mechanics formulation with the assumption that the diffusion process is modeled by linear diffusion. In models of heat flow, this assumption is based on physical experiments which tend to show that the rate of flow of heat is proportional to the gradient of the temperature. As a consequence of these assumptions, the general heat equation, u_t = div (D(u) grad u), is linearized by setting D(u) equal to a constant.

In recent modeling of many physical processes (flow through porous media, electron heat conduction, diffusion in plasmas) it has been necessary to modify the assumption of linear diffusion to more realistically capture the observed physical phenomena. Instead of linear diffusion it is sometimes assumed that the diffusion coefficient is proportional to some power $D(u) = Cu^k$. The case $k > o$ corresponds to slow diffusion while the case $-1 < k < o$ corresponds to "fast" diffusion. Mathematical analysis of the slow diffusion case establishes that if the initial data have compact support, then so will the solution for all time. Thus there is a finite speed of propagation of the flow. The terminology "slow diffusion" may be somewhat misleading since the diffusion process, while propagating at a finite speed, may not be slow compared to other processes in a physical environment (such as the speed of sound).

Research at Leiden

Peletier and his colleagues have extended this analysis beyond the case of simply "slow" or "fast" diffusion of one species. An essential feature of the problems they consider is that the diffusion coefficient may vanish, allowing for the possibility of a finite speed of propagation.

In the first problem area, Peletier and Bertsch of Leiden and P. de Mottoni of the Università dell'Aquila have been investigating the appearance and disappearance of a "mushy problem" in the Stefan problem with heating in the case where the diffusion process is nonlinear and degenerate. The mathematical problem studied is

$$u_t = (A(u)_{xx} + f(x,u) \text{ in } (0,1)x(0,\infty),$$

with boundary conditions $A(u(0,t)) = A(u(1,t) = 0$ for $t > 0$ with non-negative initial conditions. In this setup, u represents the enthalpy and A(u) the temperature of the material. The function A is assumed to be nondecreasing and, moreover, to take the constant value 1 on some interval (a,b) where b may be infinite. If b is finite, then one has a two-phase problem; otherwise, the problem is one phase. In this setup, value 1 represents the melting temperature of the material so that if $A(u) < 1$ the material is solid and if $A(u) > 1$ the material is liquid. There is considerable interest in determining the existence and properties of the "mushy region" of the solution, which is defined to be the interior of the set where $A(u(x,t)) = 1$.

Since $A(u) = 0$ on (a,b), the equation for u is a degenerate diffusion equation. Most previous investigations have been restricted to the case where A' is zero at a single point as in the slow diffusion case described above. The degeneracy requires a weak formulation of the equation. Using this formulation and some additional technical assumptions, they are able to show in the two-phase case (b is finite) that interior heating ($f > o$) sufficiently strong to cause melting will result in the development of a mushy region which disappears in finite time. This theoretical work confirms some earlier numerical work of Atthey (1974) for special initial data. With no interior heating but with the boundary condition $A(u(1,t)) = R > 1$ (so that the material is also in two phases), they are able to show that any initially existing mushy region disappears in finite time.

In another problem area, Peletier and Bertsch, along with D. Hilhorst (University of Paris-South, France) and M. Gurtin (Carnegie-Mellon University, US), have studied the diffusion of interacting species (for example, chemical or population species) that disperse in response to total population pressure. They consider the case of two species with population sufficiently dense that a continuum theory is applicable and assume that the species are undergoing dispersal on a time scale sufficiently small that births and deaths are negligible. This assumption leads them to consider the equations

$$u_t = k_1 \text{ div } (u \text{ grad } (u+v))$$
$$v_t = k_2 \text{ div } (v \text{ grad } (u+v)),$$

where $u = u(x,t)$, $v = v(x,t)$ represent the population of the two species. They further restrict themselves to the case of one space dimension and assume no-flux boundary conditions to model the fact that the species are unable to cross the boundary.

Under these assumptions, they establish the existence of at least one solution in which the two species are segregated for all time, provided that they are segregated initially. This result is quite surprising since it only re-

quires that the initial data be segregated and is independent of the values of k_1 and k_2. To derive these results, they work in a weak formulation of the problem. They do not rule out the possibility of solutions which mix – even for segregated initial conditions. They conjecture that mixing in this case cannot occur, but are currently unable to establish uniqueness of the initial value problem in this weak formulation.

They have not studied the above problem for nonsegregated initial data except for the case $k_1 = k_2$, which is much simpler to analyze. In that case, adding the differential equations for u and v, one obtains a single equation for the total population $P = u+v$. Using this reduction, they are able to prove uniqueness within the class of all solutions and can show that solutions which begin mixed remain so for all time.

Conclusion

Peletier and his colleagues are analyzing mathematically the qualitative properties of solutions to various degenerate nonlinear diffusion processes. This basic work, while on model problems, should provide insight concerning the appropriate modeling of realistic complex physical processes and their associated behavior. Let us hope that the diffusion of these techniques and results into the engineering and physical science communities will not be of a degenerate diffusion type with an extremely slow speed of propagation.

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3/22/85

Mathematics Research at CWI, Amsterdam

by Charles J. Holland. (This article was originally published in June 1985 [ESN 39-6].)

The Netherlands' Center for Mathematics and Computer Science recently has received stimulation grants to transfer advanced mathematics to Dutch industries and governmental agencies. The CWI (for Centrum voor Wiskunde en Informatica) conducts basic and applied research in various areas of the mathematical sciences, with special attention to those areas which may have applications in the Netherlands.

In this article I will give an overview of the center and then focus on the research activities in numerical analysis, including several projects which are involved in the transfer of advanced mathematics to applications.

Background

The CWI, located in suburban Amsterdam, is the research center of the nonprofit Foundation Mathematical Center (SMC for Stichting Mathematisch Centrum). It was founded in 1946 through the efforts of Professor van der Corput to give a focus to the Dutch mathematical community, which had been fragmented during the war. Until 1983 the SMC was known as the Mathematisch Centrum, but the name was changed in 1983 to give a better description of its research activities. Since the center's founding, computer science has been an important activity, so the name change does not reflect an expansion of the research interests. In fact, the first Dutch computer was designed at the center and was later built by Philips.

Organization

The current scientific director of the center is Professor P.C. Baayen, who heads the six research departments: Pure Mathematics, Applied Mathematics, Mathematical Statistics, Operations Research and Systems Science, Numerical Mathematics, and Computer Science. The total staff is approximately 150, including support personnel. The research staff of approximately 80 is made up of approximately 40 percent full-time appointments. The remaining 60 percent are divided among postdoctoral personnel, who have a limited term appointment of 3 years, and master's level students. Typically, these master's level students have completed 6 years of course work and are given a 4-year appointment to write a doctoral thesis.

Funding

In 1983 the budget of the CWI was approximately 13 million Dutch guilders (currently there are about 3.6

Dutch guilders to the dollar, but in 1983 there were approximately 2.8). Of this total, approximately 11 million guilders were received directly from the Dutch government through The Netherlands Organization for the Advancement of Pure Research (the ZWO), which can be considered the equivalent of the US National Science Foundation (*ESN* 38-8:438-442 [1984]). The remaining funds, approximately 15 percent of the total budget, arise from various sources, including contracts, publications, and courses.

Currently, additional funds are available from the new Dutch program to stimulate research transition to industry. If an industry expresses interest in a particular research application, then the Dutch government, through the Foundation for the Technical Sciences (STW), will provide support to enable its transition. In this arrangement, the industry is not forced to provide cost sharing, but only to interact with the research personnel. There are currently six of these projects ongoing at CWI. A larger source of additional funding is a 5-year grant for 2 million guilders annually as a result of CWI's being designated by the national government as the Dutch center of excellence for computing.

Trends

Under the direction of van der Corput, the CWI started as a fairly applied institute; as mentioned above, the first Dutch computers were developed there. In the past, efforts shifted to a more theoretical nature, but that trend may be reversing. Two reasons expressed for this shift were: (1) many mathematical tools have been developed which are now capable of being applied, and (2) there appear to be more interesting mathematical problems in industry. But another reason for this shift is that there are the additional funds from the Dutch government to work on these problems of interest to industry.

Research Activities in Numerical Analysis

In the rest of this article, I will concentrate on the activities in numerical analysis with a brief overview of some of the other departments. Professor P.J. van der Houwen heads the Numerical Mathematics Department. Researchers there are interested mainly in initial and boundary value problems for partial differential equations and in numerical software development. The topics under investigation are a combination of both theoretical research and applied (or contract) research.

Theoretical work on initial-boundary-value problems is concentrating in the areas of stability and convergence of numerical schemes for solving nonlinear differential equations. This stability and convergence work relies heavily on 1975 work of G. Dahlquist and has been reported in a monograph by K. Dekker and J. Verwer (1984).

The applied work on initial value problems is focusing on two-dimensional hyperbolic schemes with reduced dispersion and on the incompressible Navier-Stokes equations. In a project sponsored by the STW, the goal is to apply the theoretical work undertaken at the CWI to develop an efficient vector code for the Cyber 205 for solving shallow-water equations. This code, being developed under the stimulation scheme discussed above for the National Hydraulics Laboratory, will be an explicit scheme to exploit the specific characteristics of the Cyber 205, the scheme will replace a very good sequential scheme using an alternating direction implicit scheme. The shallow-water equations consist of three linked partial-differential equations for the velocity vector and the rise of water level under the influence of tides or winds. The problem, of tremendous importance to the Netherlands, is to be able to calculate the velocity vector and rise of water level as functions of time and place for any configuration of coast, floor profile, and obstacle as well as for given external forces such as wind and friction.

Theoretical research on boundary-value problems is concentrating on the development of multigrid methods. This work has emphasized general linear second-order elliptic partial differential equations on a rectangle in two dimensions with either Dirichlet, Neumann, or mixed boundary conditions.

In cooperation with the Delft University of Technology, the researchers have developed two portable algorithms (not machine dependent) for these problems. The first version is intended for the usual sequential (scalar) computer, while the other is aimed at vector computers (such as versions of the Cray or the Cyber 205). In both cases they have not used features that are machine dependent but have instead written the program in the most elementary and portable Fortran. This means, for the vector code, that they have used the auto-vectorization capabilities of the Fortran compilers. Of course, a faster multigrid algorithm could be written if one restricts oneself to one machine and, even faster yet, if one restricts oneself to a particular equation. For example, Barkai and Brandt (1983) have constructed a special multigrid program for the Cyber 205 which solves only the Poisson equation.

The contract work on boundary value problems is concentrating on the development of a Cyber 205 code, to be used by the Dutch National Aerospace Laboratory for solving the steady Euler equations describing nonviscous gas flow problems.

Work on software development is using a European community grant for the development of ADA software for numerical algorithms. This is a joint project with the UK's Numerical Algorithms Group (NAG) and National

Physical Laboratory, and Trinity College in Dublin, Ireland.

Other Research

Professor J.K. Lenstra heads the Operations Research and Systems Science Department, which concentrates in combinatorial optimization, systems and control, networks and queues. The unifying theme in this research is the development of techniques that can aid in decision making. One special focus of the department is the investigation of the use of parallel computer architectures and algorithms for applications to operations research problems. While there has been significant research activity in the investigation of parallel algorithms for modeling large-scale physical systems (for example in computational fluid dynamics), the application of parallel algorithms to the operations research arena appears relatively new. The researchers expect that their future research in this field will examine the parallelization of enumerative methods, such as dynamic programming and branch and bound. They are currently interested in applying their algorithms to existing multiple-instruction multiple-data machines such as the Denelcor HEP.

The Applied Mathematics Department, headed by Professor H.A. Lauwerier, is concentrating in biomathematics, stochastic aspects of dynamical systems, and asymptotics and applied analysis. In the last area, N.M. Temme and C.G. van der Laan (1984) have published a CWI tract discussing the numerical computation of special functions such as the Euler gamma function, the exponential integrals, and the error functions.

The fundamental work in the Mathematical Statistics Department, now headed by R. Gill, has been concentrating on semiparametric statistics to model real-life cases in which one part of the situation has a very specialized structure and the other part is unknown. Gill is interested in generalizing the concepts of maximum likelihood to nonparametric cases. The applied work in the statistics department is concentrating on discriminant analysis; the researchers want to develop automatic classification schemes. Gill reported that he would like to see his department move more in the direction of computational methods in statistics, including stochastic geometry and the analysis of images. He reported, however, that he was having difficulty in obtaining professionals in these areas.

Conclusion

Researchers at the CWI are doing an excellent job of combining basic research with applications. This is especially evident in the work in numerical analysis, which is leading to the development of very efficient codes for practical fluid dynamics applications.

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3/22/85

OCEAN SCIENCES

Marine Science at the Netherlands Hydraulic Laboratory

by Jerome Williams. (This article was originally published in November 1987 [ESNIB 87-01].) Professor Williams was the Liaison Scientist for Oceanography in Europe and the Middle East for the Office of Naval Research's London Branch Office from December 1985 to December 1987.

Remote Sensing

While in the Netherlands I visited with Dr. Daniel Spitzer, who is head of the newly created section on remote sensing within the Tidal Waters Division of the Ministry of Transport and Public Works. The objective of this section is to determine the remote sensing techniques that can best be applied to the assigned tasks of the division. Initially they will be working in three specific areas which include:

- The use of current-measuring radar, primarily for sediment transport studies
- Use of electromagnetic bathymetry systems, including both microwave (synthetic aperture and side-looking

aerial radars) and laser techniques, not only to measure water depth but also to obtain information about the optical properties of the water column

- The development of improved methodologies to enhance interpretative skills in the analysis of passive sensor data from systems such as the Thematic Mapper.

At the present time the group appears to be concentrating on the effective use of data obtained from sensors flown from aircraft. In particular, they are attempting to develop algorithms that will improve the utility of both microwave and laser instruments and allow for the extraction of bottom information from multispectral data. The group is small, but it includes a few people such as Spitzer who have an excellent record in previous activities of this kind.

The Hydraulic Laboratory

My visit to the Hydraulic Laboratory at Delft was a little different from most other visits made there, since I concentrated on the estuarine and coastal aspects of the laboratory. Dr. Robert Uittenbogaard, research engineer in stratified flows, showed me around the physical facilities of interest – in particular, the physical hydraulic model of the Rhine-Meuse estuary and the laboratory tidal flume.

The Rhine-Meuse model has a horizontal scale of 1:640 and a vertical scale of 1:64. It is very well instrumented and computer controlled, so it is particularly well suited to tidal motion, salinity intrusion, and pollutant dispersion studies. With the recent popularization of computer models, many physical models have fallen on hard times, but the Dutch are not giving up on the physical models completely without something demonstrably better to take their place. The Delft Laboratory's plan appears to be to gradually phase out the use of physical models as the computer models become reliable enough for operational use. Housed in a large, well-constructed building, the Rhine-Meuse model will be more than adequate as long as the staff wants to use it.

The tidal flume is an interesting device used primarily to study estuarine sediment transport and stratified flows. As may be seen from Figure 1, a model "sea" is connected to a long flume in such a manner that tidal motion can be simulated and sediment can be injected into the system at either (or both) the ocean or river end of the system. The flume consists of 21 replaceable sections, making a maximum length of 130 meters possible, which allows simulation of a complete tidal cycle. The width and height of the flume are both 1 meter, a tidal range of 0 to 15 cm with periods ranging from 30 seconds to 1 hour can be produced, and sediment concentrations of up to 3000 mg/l are possible. A special information system was developed to control sea and boundary conditions and to sample, store, and process data using a VAX 730 as a central facility. The system is designed so that data collection is initiated as soon as the flume reaches the required experimental conditions. It is possible to measure water level at 15 positions along the flume as well as vertical profiles (10 to 20 points) of salinity, velocity, and silt concentration. These data are continually monitored by the VAX 730 to ensure adequate data quality, and only those data meeting predetermined criteria are stored for final processing by the laboratory's main computer, a VAX 750.

The Delft Hydraulics Laboratory is run by the Ministry of Transport and Public Works, and it includes the following divisions: estuaries and seas; water resources and environment; rivers, navigation, and structures; harbors, coasts, and offshore technology; cutting and dredging technology; industrial hydrodynamics; hydrosurveys; and research and information technology. Of these, I was primarily interested in the work of the estuaries and seas division, which focuses on mixing, sediment transport, and pollution studies.

The Estuaries and Seas Division. This division is heavily involved in the development of mathematical models to support the mixing, sediment transport, and pollution studies, and has a large battery of computers

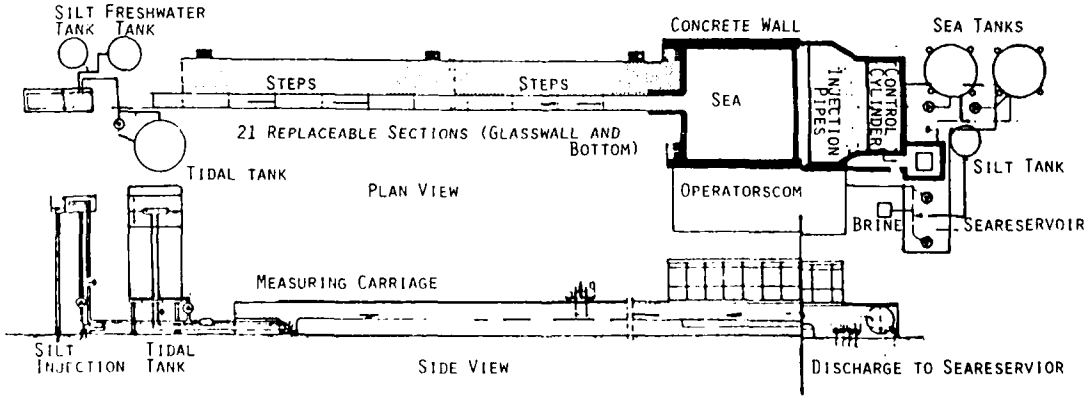

Figure 1. Top and side views of the tidal flume.

(Cray-1, Cyber 205, and several lesser VAX, Sperry, and IBM units) available for their use. Dr. Herman Gerritsen of the division's coastal seas oceanography group filled me in on some of the ongoing work in storm surge modeling of the northwestern European continental shelf. This area, with a flushing time of several years, is extremely important to all of Western Europe. The model has a grid size of 3x5 nautical miles and has been used primarily for ship routing, but it has recently been extended for use in modeling the subgrid tidal circulation. So far the investigators have found a strong dependence on bottom topography and a marked disparity between vorticities determined at the small grid scale and those associated with larger grid sizes.

Another modeling project is concerned with fronts in the North Sea. They are using a combination of thermal and haline stratification in an effort to develop a model that can be used for pollution dispersion prediction. An integral part of the effort involves the development of methods to facilitate the assimilation of satellite data, especially IR data, into their models. In this effort they are being funded by the European Space Agency (ESA) as part of the ERS-1 verification program.

Studies in Fine Cohesive Sediment Problems. Although he was just about to move to a new job with the Department of Public Works, Mr. W. Van Leussen took time to discuss the Hydraulic Laboratory's program in fine cohesive sediment problems with me. These problems develop as a result of dredging and erosion, and have pollution connotations as well as more basic ramifications. Various studies involving sediments are underway at the laboratory involving transport, using the tidal flume described above; bottom layer processes, using a specially designed bed model; and settling processes, using the laboratory's settling column.

The settling column is slightly over 4 meters high and 30 cm in diameter. It contains a series of oscillating wire grids which serve to maintain a minimum turbulence level in the tube (see Figure 2). This turbulence, which will tend to increase the frequency of particle collisions and therefore enhance flocculation as well as increase the shear stress (tending to limit floc size) is continually monitored by the use of a laser Doppler turbulence meter. Experiments to determine the change in settling rates with large and small particles present in large and small concentrations were performed. It was found that settling proceeded more rapidly under conditions of high concentration (1000 mg/l) than low (50 mg/l), probably due to higher flocculation rates. In addition to measurements of vertical velocity and sediment concentration made at various points in the column, movies have also been made which show very clearly the effect of increasing particle size due to flocculation.

Laboratory column studies have been supported by other laboratory studies and field work in addition to some modeling activity and by an active interest in the chemical uptake properties of sediments. These have been pursued both from the point of view of pollution prevention and the possible use of specific tracers for sediment tracking. There is also some interest in larger size particulates (sand), particularly with regard to the stability of coastal sand beaches. Wave effects on beaches and the stability of sand slopes are just two of the topics under consideration.

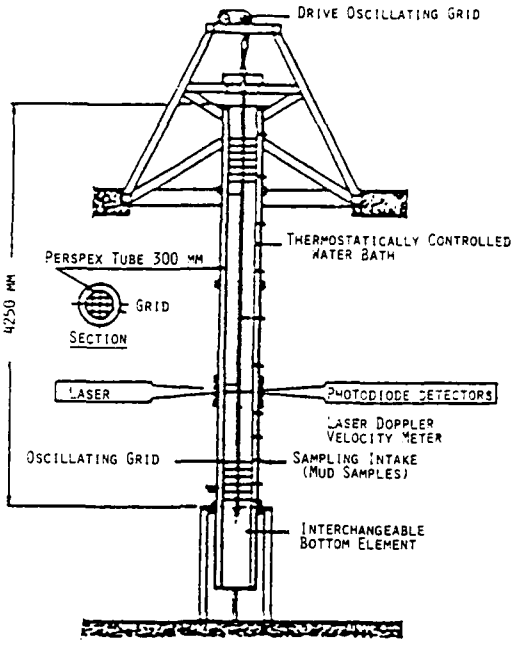

Figure 2. The settling column, showing many of its components.

Conclusion

The Hydraulics Laboratory at Delft is a very impressive facility. It is very large, very modern, very well run, and very well maintained. The Dutch have a long tradition of world class excellence in this area, and I saw ample evidence that they intend to maintain world leadership. The fact that physical and numerical models are both being used, each for solution of the most appropriate problem, indicates an understanding of the nature of the real world which many other laboratories do not share. The level of technology demonstrated by this institution is impressive, but what is really impressive is the uncanny ability of these people to employ this technology as effectively and efficiently as they do. The people at Delft are well supported with exceptionally good tools to do their job, and I got the distinct impression that they were well aware of the quality of this support.

7/20/87

PHYSICS

Gas Laser Research at Twente

by Paul Roman. (This article was originally published in February 1987 [ESN 41-2].) Dr. Roman was the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office from September 1984 to September 1988.

The Department of Applied Physics at the Twente University of Technology, Enschede, the Netherlands, is the leading Dutch center for lasers and laser system development. Its vigorous, internationally highly respected founding director, Professor W.J. Witteman, has built up in the past 18 years a well-equipped, well- housed, well-staffed institute. His only complaint is that, outside of Europe, insufficient attention is given to their work at Twente. Perhaps this article will help to close the info-gap.

The institute concerns itself only with (very different kinds of) gas lasers. All research is on the "basic" level; development activities are not pursued. Current activities can be grouped as follows:

- Excimer lasers
- CO lasers
- CO_2 lasers
- Electronionizationatomiclasers
- Generationofmid-Irradiation.

I think that the most noteworthy work done is in the area of excimer lasers, specifically research with noble gas halides. In this article I give a more detailed description of this activity but find it important to identify, however briefly, the other four areas of activity as well.

Noble Gas Halide Excimer Lasers

XeCl, ArF, KrF lasers (and devices with mixture of these compounds) are the subject of intensive work, which follows two lines: (1) discharge pumped and (2) e-beam pumped excimer lasers.

In the first group, one of the recent results is the successful excitation of a KrF laser by a capacitively coupled longitudinal discharge. The point of this research, carried out by T. Gerber, P.J. Peters, and H.M. Bastiaens, was to produce a very simple, miniature, compact-action laser, which operates on the principle of single discharge. The discharge is produced in a 25-cm-long quartz tube (inner diameter, 4 mm; wall thickness, 1 mm) between two stainless steel electrodes at its end and the inner tube wall (which serves as a dielectric electrode). The dielectric electrode is capacitively coupled to a metallic electrode surrounding the quartz tube coaxially. The driving voltage is 100 kv (with a risetime of 20 ns). The gas mixture $He/Kr/F_2$ was kept at pressures between 0.5 to 3 bar. The KrF laser action gave a radiation with 248-nm wavelength, with output energies up to 1 mJ in pulses having a duration of 6 ns.

Related work was done by G.J. Ernst, A.B.M. Nieuwenhuis, and K.M. Abramski (the latter from Poland) on a corona-preionized XeCl laser. The experiment involved two innovative features: first, a very elaborate pulsed-power and power-shaping system to obtain a self-sustained avalanche discharge; and second, high pressures in the gas mixture. Both $He/Xe/Cl_2$ and $Ne/Xe/Cl_2$ mixtures were used, and pressures from 5 to 12 bars were arranged for. Very high output power and good efficiency was obtained in this way. Actually, the maximum output energy per unit volume was as high as 9 J/l. Experiments indicated that the output-energy scales with pressure. The output times were very short (about 100 ns), and the authors assert that this can be further shortened by using a longer waterline.

The second area of investigation with noble gas halide lasers (i.e., e-beam pumping) was started several years ago. (For earlier work see B.M.H.H. Kleikamp and W.J. Witteman, *Optics Communications*, 49, [1984] 345, and literature quoted therein.) The major purpose of this research is to achieve unusually high output per unit time or per unit volume, as well as to have acceptable efficiency. While the discharge-pumped high-pressure laser (described above) already went some way toward this goal, the results with the Twente group's high-pressure, e-beam pumped, KrF lasers are considered as an "international first," as Witteman proudly pointed out to me. Both coaxial and plane-axial e-beam pumping have been investigated. The researchers were specifically interested in operating the lasers at unusually high pressures. The experiments dramatically confirmed their expectation to the effect that the output power will increase drastically with pressure.

The energy transfer from the e-beam is proportional to the gas density, but the density must be limited because of its quenching effect and the production of absorbing species. (Incidentally, Witteman's group found that quenching is more significant than absorption for the noble gas halide lasers, as opposed to pure noble gas systems such as Xe_2.) Since for high performance one has to optimize the balancing process between the excitation of the gas and its quenching and radiation losses, it became necessary to investigate mixtures with different

buffer gases that are expected to show significant differences in their quenching and absorption properties. Whereas the classical mixture for a KrF excimer laser is $Ar + Kr/F_2$, the Twente researchers recently found that better results can be obtained with a $Ne + Kr/F_2$ mixture. Using 23-atm total pressure, they obtained, in a 16-cm^3 volume, 1 J energy output at 195-nm wavelength. The pulses had 50-ns duration. (Thus, the output power density was about 10 MW/cm^3.) The experimental setup in this experiment consisted of a coaxial vacuum diode driven directly by a low-inductance 10-stage Marx generator and a laser chamber made of 50-μm-thick Ti foil. The diameter of the chamber was 1cm and the pumped length 20 cm. (Corresponding active volume: 16 cm^3.) The charging voltage was 280 kV and the charging current 7.5 kA, delivered in 30-ns pulses. (From these data, the estimated maximum current density in the tube was 375A/cm^2 and the average current 250 A/cm^2). The maximum electron energy inside the tube was about 170 keV.

In currently running experiments, a bigger tube is being used. Here the energy output is a respectable 12 J/600 cm^3, in 250-ns pulses.

The detailed studies can be summarized by saying that the lighter the buffer gas, the higher the maximum extracted energy density; but also that this higher energy is extracted at a higher pressure of the buffer gas.

Incidentally, as a byproduct of these optimizing experiments, the researchers could also determine (for the first time) the quenching factors of Kr and Ne (they are 4.6×10^{-31} and 1.5×10^{-32} cm^2/sec, respectively.)

CO and CO_2 Lasers

I understand that Witteman is one of the foremost experts in the area of sealed CO lasers. One of the primary achievements in this field was the construction of a long-life device (see Figure 1) which could operate at room temperature in a tuneable way, and in CW-type operation. It was made transition selective by using a three-mirror configuration. With this arrangement, it was possible to tune the laser to more than 70 oscillating vibrational-rotational transitions, thus giving emissions between 5.2 and 6.1 nm. (Some lines in this range were missing, probably as a result of atmospheric absorptions.) In multiline operation, the output was 20 W/m. The output power of the different lines varied between 25 mW and 2W, but steps are being taken to improve the output. This will be done by means of increasing losses in the cavity, so that no transition can oscillate without the grating. The efficiency is now exceeding 16 percent. In related experiments, a pulsed CO laser was studied. Here UV or x-ray preionization was employed.

The associates of Witteman in the CO laser research are P.J.M. Peters, Z. Kryzanowski, J. van Spijker, and (from Poland) K.M. Abramski.

In the field of CO_2 lasers, I think two research efforts should be reviewed. The first is a joint effort of Witteman and R.A. Rooth and is directed toward the realization of a single discharge system with a very large aperture. Much attention was given to the increasing of energy extraction. One device in these studies was a transversely excited atmospheric (TEM) laser amplifier. The amplifier was excited by a 1.1-ns pulse consisting of an adjustable number of lines generated by a novel mode-selected multiline oscillator. An increase in energy extraction of 95 percent with respect to single-line extraction was achieved, with a pulse consisting of up to six lines in the 10.6-μm branch. The preliminary results were published about a year ago (*Journal of Applied Physics*, 58, [1985] 1120), but many new results are contained in the unpublished doctoral thesis of Rooth, defended in May 1986. (Copies are available from me.) One of the newer results is that the experiment has been extended to achieve multiple-pass amplification. It appears that multiple-pass amplification is the best way to obtain an increase in efficiency of amplifiers for nanosecond pulses. Also, it is essential to have a rich multiline operation. The maximum extracted energy density in the recent experiments was 9.7 J/l, at an efficiency of 4.3 percent. A good round-trip time was found to be about twice the Fermi relaxation time (35 to 60 ns at 1 atm). Perhaps I should note here that this research is not purely academic: increasing the efficiency of nanosecond-pulsed CO_2 lasers has great importance in laser radar and certain types of laser fusion work.

A second line of research with CO_2 lasers concerns itself with high-pressure (10-20 bar) devices, which work with an x-ray preionization system. Short pulse operation of these lasers is a primary goal, along with high efficiency.

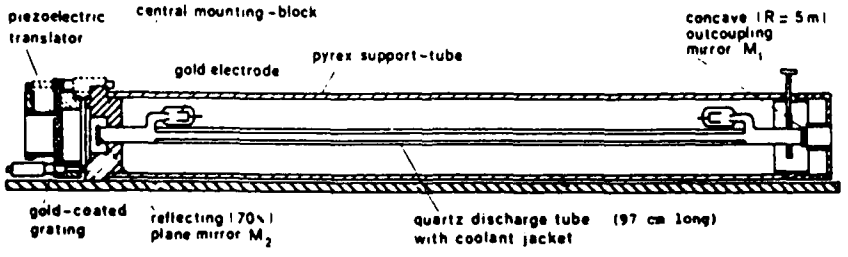

Figure 1. Tuneable CO laser construction.

The short pulse behavior is studied with the help of nonlinear optics techniques.

Electron Ionization Atomic Lasers

These are a not well known, rather novel type of lasers. The basic idea is to use some noble gases (or some combinations thereof) and first excite the atoms from the ground state into a metastable state and then bring them to an excited level, from which the laser action starts. The basis of this idea can be found in early Russian research on pulsed discharge lasers. In practice, Witteman and colleagues have achieved the transition to the metastable state by using high-energy e-beam ionization. (In the discharge, there will be many atoms in the metastable state.) Their next step is to maintain a discharge at much lower energy; this will bring the metastable-level atoms into an excited stable level.

The radiation achieved in this way (by methods quite similar to those used for excimer lasers) will be in the near-infrared region. The advantage over a CO_2 laser would be high efficiency (up to 10 percent) and the elimination of problems related with gas dissociation at high temperatures.

Experiments at Twente in this area are in a preliminary state and no details are available at this time.

Generation of Mid-Infrared Radiation

The last of the areas of Twente's research that I wish to mention is the generation of mid-infrared radiation. There are two research lines toward this goal. The first is somewhat conventional: using a CO_2 laser for optical pumping, 16-μm coherent radiation is created in a simple CH_4 resonator.

The second approach is based on stimulated Raman emission. The source is a pulsed CO_2 laser. The emission is directed into a Raman cell (constructed as a multipass amplifier and filled with para-hydrogen); the stimulated Raman emission occurs at a wavelength of 16-μm. Currently, the experiment is conducted at liquid nitrogen temperature, but Witteman believes that eventually room-temperature operation will be possible.

12/01/86

SEMICONDUCTORS

Siemens and Philips Work in Submicron Technology for Integrated Circuits

by J.F. Blackburn. (This article was originally published in March 1987 [ESN 41-3].) Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.

Considerable publicity has been given to the so-called Mega Project, which is a code name for a joint venture between Siemens of West Germany and Philips of the Netherlands. The aim of the project is to develop submicron technology needed for the mass production in the late 1980's of very complex integrated circuits with smaller structure and greater memory capacity than can be produced with present technological facilities. Specifically, in the Mega Project Philips in working on a 1-megabit static random access memory (SRAM) chip, while Siemens is developing a 4-megabit dynamic random access memory (DRAM) chip.

These 1- and 4-megabit RAM's are being developed on the basis of complementary metal oxide semiconductor (CMOS) technology. Analog integrated circuits are used as voltage regulators, amplifiers, receivers, and color TV circuits. The transistors in these chips operate with analog signals, and amplify vibrations or voltages. However, transistors in digital integrated circuits work as relays and as switches based on the on/off principle, and are used in watches, compact disk players, Teletext machines, and personal computers.

In digital integrated circuits there are logic circuits and memory circuits. A logic circuit may be a microprocessor chip constituting the arithmetic unit of a microcomputer. Another use is in video recorders for use in functional control. Memory chips, on the other hand, are integrated circuits regular in structure and able to accommodate a much higher number of components.

Chips may work with bipolar transistors or with metal oxide semiconductor (MOS) transistors. The bipolar transistors can operate faster than MOS transistors and

they deliver higher power, and consequently generate more heat. MOS integrated circuits can be made more cheaply than digital integrated circuits and they generate less heat. This permits greater density. They are primarily suitable for digital functions.

CMOS circuits use both electrons and holes (absences of electrons) and they are highly suitable for memory chips. They have the advantages of simpler construction, a smaller surface area, and lower energy consumption than bipolar circuits. The lower energy consumption, and consequently less heat generation, is vital in the fabrication and use of very high-density integration. Thus, there are strong technical reasons for choosing CMOS technology for the Mega Project.

It was agreed in the beginning that Siemens would concentrate on the dynamic RAM for 4-megabit chips and Philips would work with the static RAM for 1-megabit chips.

Apart from the above, Siemens has purchased from Toshiba technology for imprinting circuits on the 1-megabit DRAM. This was done in order to get this memory chip to market in 1986. These chips are now being delivered to selected users and will be available for extensive delivery in 1987.

The 4-megabit chips will be delivered to selected users in 1987 and available for more extensive delivery in late 1987 and early 1988.

Both Philips and Siemens are using light optics in the Mega Project. The optics developed at Philips research laboratories are called I-line optics because they deal with the I-line of the mercury spectrum. The wavelength of 365 nanometers allows submicron structures to be produced on a chip. A mask consisting of a glass plate with an image of the structure to be produced on the chip, enlarged 10 times, is projected as a reduced image onto the surface of a silicon wafer covered with a photoresist film. After exposure the silicon wafer is shifted and the structure is projected again. The entire silicon wafer is covered step by step with identical patterns. For this reason the process is called "wafer stepper." In the succeeding step, a photoresist film is applied again and a new structure is projected with an additional mask.

Various problems arise in submicron technology that are more complex than those handled by tested methods for less miniaturized circuits. One problem is that of transistor isolation normally done by local oxidation of silicon. But the isolating SiO_2 layer grows as a beak under a protective layer of silicon nitride, which causes a loss of isolating surface – a serious problem in high-density circuits.

In miniaturization a strong electrical field is created near the drain electrode. The resulting high-energy electrons threaten the stability of the component. This destabilization can be countered by producing an additional isolating layer on the gate level.

In miniaturization the vertical dimension must also be reduced, requiring flatter ion implantation. This can lead to excessively high electrical resistance. To counter this problem, a thin metal layer is deposited after ion implantation on the silicon by ion sputtering. During the heat treatment the silicon reacts with the metal and forms low-resistance silicides. Nonreagent metals can then be etched away.

The process step of etching holes in the oxide layer leaves an uneven surface which must be leveled for the next step. One method of leveling is to deposit a metal layer on the surface through precipitation from the gaseous phase (chemical vapor deposition) to fill the holes. Metal deposited outside the holes must then be etched away. Another method is based on the fact that the bottom of the hole consists of silicon and the walls consist of silicon dioxide. It is possible to deposit material selectively on the silicon to fill the holes.

The design of the complex circuitry and the calculation of the electrical behavior of a 1-megabit SRAM containing over 5 million transistors and the manufacture of the masks for its production requires high-performance computers and complex software. Test software is used to isolate a defective chip on a wafer and then defective memory cells on a chip. Unless the number of defective memory cells is excessive the chip can be repaired by a laser. Additional elements are included on a chip and these can be included in the circuitry to replace defective elements with the use of a laser.

Beyond the 1-megabit chip and the 4-megabit chip there is possible close cooperation between Philips and Siemens and possibly other European partners like Thomson and General Electric Company (GEC) in developing microprocessors of the 1990's. Discussions have been held concerning the future development of a 64-megabit chip. This may eventually lead to a joint EUREKA proposal.

Siemens sees "chip" technology as the key to the company's future and has therefore made massive investment in plant, equipment, and personnel to achieve a highly competitive world position in this field. Siemens expects to remain among the world's leading suppliers of electronics components.

Reference

"Siemens, Philips Megachip Project Achieves Progress," *Frankfurt/Main Die Umschau*, No. 5, (June 1986), 334-335. (Excerpt in English JPRS-EST-86-011-L, 2 October 1986, 44-46).

12/16/86

DUTCH INDUSTRIAL TECHNOLOGY IN ACTION

RDM–Finesse and Precision in Heavy Fabrication, Manufacture

by R.H. Taylor. CDR Taylor is the Undersea Systems Officer in Europe and the Middle East for the Office of Naval Research's London Branch Office.

The Background

De Rotterdamsche Droogdok Maatschappij b.v. (RDM) was founded in 1902 as a company specializing in the repair of ships and their equipment. Within a short time, building of merchant as well as naval vessels was added to the company's growing range of activities.

In the merchant marine sector the building of two luxury liners, the *Nieuw Amsterdam* and the *Rotterdam*, formed a milestone in RDM's history. Starting in 1930 the development and construction of submarines became a company speciality in the defense sector; these submarines gave outstanding performance in service with the Royal Netherlands Navy. In the same period the production of guns and howitzers for navy and army applications added to the product range – production that became an important base for RDM's present position in this field.

Today RDM is an independent company employing approximately 1500 people. Although RDM operates under normal commercial market conditions, a special relationship with the Dutch Government has developed in the defense as well as in the civil sector, resulting in a good understanding and efficient communications. On the basis of sound financial results, RDM is able to continually invest in development of its current products and future markets, as well as in equipment, production control, and human resources.

High technology plays a major role in RDM's success. Tight and effective project management and production control, extensive use of CAD/CAM systems, and application of its technological experience to translate customer specifications into quality products are all involved in expressing that technology in advanced hardware. RDM's products are in the main intended for rather individualistic markets such as the energy and defense sectors. RDM's activities are divided into three industry groups: Naval Engineering, General Engineering, and Energy Systems. Defense Engineering is an important part of the industry group, General Engineering.

Naval Engineering

In close cooperation with the government and the Royal Netherlands Navy, RDM has gained wide experience in the design and construction of ocean-going submarines. This is epitomized in the current product range: the 2800-ton *Walrus* Class and the range of submarines designated as the *Moray* Class, a flexible design having 1100- to 1800-ton submerged displacement. These products have several elements in common: integration of proven equipment, low noise levels, high shock resistance, and outstanding cost-effectiveness.

RDM's range of submarines provides great flexibility of design in response to various customer requirements. A further development of the very effective *Walrus* Class led to a MK.2 version that allows the integration of enhanced propulsion systems, large batteries, or an air-independent propulsion (AIP) system.

As part of the family of submarines, to which the *Moray* Class belongs, a concept has been developed with includes elements of the *Walrus* philosophy combined with the modular flexible design advantages of the *Moray*. This class, named *SUB.21*, has a submerged displacement of 2400 tons.

General Engineering

The General Engineering industry group develops and supplies advanced products and systems for civil and defense markets. One example is the role RDM played during the construction of the Eastern Scheldt Storm Surge Barrier, one of the largest hydrodynamic projects in Europe, if not in the world. As prime contractor, RDM was responsible for management, manufacturing, installation, and start-up of the 124 hydraulic opening and closing mechanisms of the gates.

Defense Engineering. Within the General Engineering industry group Defense Engineering forms a main field of activities. Ordinance has been a specialty for many years. The present production program includes the manufacture, upgrading, and modification of towed 155-mm field howitzers, self-propelled howitzers, and antiaircraft guns.

Modification and production of wheeled and tracked vehicles (armored personnel carriers, reconnaissance vehicles, etc.) and systems for main battle tanks form another range of activities. Antitank missile launchers have

been integrated into armored personnel carriers. RDM's Defense Engineering has gained wide experience in the fifth-echelon overhaul of heavy armed vehicles and weapon systems. Another Defense Engineering product that has found wide acceptance is RDM's helicopter landing-grid, permitting helicopter operations on board ships in conditions up to sea state 6-7.

Energy Systems

Steam turbines and ancillary components for coal-fired and nuclear power-generating plants form one section of the production activities of Energy Systems. The other section is the production of pressure vessels for the petrochemical and oil and gas industry as well as for nuclear steam generating plants and structural components for the offshore industry.

RDM has extensive experience in the use of special steels and weldoverlay cladding, now demanded for more aggressive processes.

RDM has the personnel to see projects through from inception through project management to after-sales services, including instruction and maintenance.

RDM's Facilities

RDM's location offers unique possibilities for transport. The premises are situated on one of Europe's main waterways, in the world's biggest port, Rotterdam, with free access to the major European industrial areas on the one side and the ocean on the other.

The plant includes various machining, construction, and welding workshops, that are, in particular, capable of accommodating very large and heavy equipment. RDM has the know-how, facilities, capacity, and quality control necessary for advanced welding, machining, and heat treatment of a large range of materials. Their machine tools include a wide range of CNC machining centers, such as horizontal and vertical turning centers with full 3-axis contouring capabilities.

Chemical and metallurgical analysis, nondestructive and hydrotesting, and measurement facilities are indicative of high standards, as reflected by RDM's AQAP-1 certificate.

RDM has authorization for the use of ASME "U" and "U2" stamps and complies with German, British, Dutch, and other codes and standards.

9/14/88

Systems and Applications – a Sampling

The notes which follow are intended to provide a quick, across-the-board impression of Dutch technology – of systems and applications work in the Netherlands. These notes have been assembled from ONRL's Military Applications Summary Bulletins and reports by personnel of the European Office of Aerospace Research and Development.

European Wave Model Tested. A group of European scientists has tested a new computer model for wave forecasting which has promise of minimizing casualties to men and equipment caused by unexpected high seas. The scientists used a spectral approach to resolve waves with periods between 2.4 and 25 seconds and arriving from all directions on a 12-point compass. The model has been tested on three geographic grids: 3 degrees x 3 degrees (global); 1 degree x 1 degree (North Atlantic); and one-quarter degree x one-half degree (North European continental shelf). Four unpublished papers from the Netherlands Meteorological Institute are available about this model and its test: "A Third Generation Ocean Wave Model," by G. J. Komen and L. Zambresky; "The Results with a Third Generation Ocean Wave Model," by G. J. Komen; "The Numerical Simulation of Ocean Wave Evolution on a Cray-XMP48," by G. J. Komen and P. A. E. M. Janssen; "Activities of the WAM (Wave Modeling) Group," by G. J. Komen.

Advanced Composites and Information Technology at Devtech. The Devtech company in Heerlen uses a strong mathematical basis founded in topology to solve, with the aid of artificial intelligence, complex materials, engineering, and information technology problems. Materials developed include *in-situ* ceramic-ceramic composites, claimed cheaper to produce than cast iron. Intelligent manufacturing of thermoplastic composites is being scaled to large size. In the information technology area, data compression of 10,000:1 has been demonstrated.

Holographic Night Goggles. OIP Instrubel, a Netherlands company, has recently developed the HNV-1, lightweight, single-tube night goggles. The use of ho-

lographic optical elements (HOE's) provides the unique feature of a see-through image and allows a compact optical layout. This very use of holographic technology, which differentiates the HNV-1 from all other night vision goggles, allows the operator to perform night tasks under even better conditions than could ever be achieved with classical night-vision goggles; such tasks can be performed as driving vehicles, flying helicoptors and other low-speed aircraft, map reading and maintenance, loading and unloading at night, mine laying, and night patrols and surveillance. HNV-1 goggles also find many applications for nonmilitary uses.

Automated Meteorological Information System. The Meteorological Organization of the Royal Netherlands Airforce (RNLAF) has, with Sigmex Systems, developed a fully automated Meteorological Information System (MEIS) which provides the latest in networked computer systems and advanced graphics workstations to support the meteorologists of the RNLAF in the provision of reliable short-duration weather forecasts to aid in all aspects of mission planning. Special emphasis in the design has been placed on the fact that incoming information from many different sources has to be stored, collated, analyzed, and possibly redistributed automatically by the system, irrespective of whether or not the workstations are manned.

Archimedes II: Remote Sensing of Oil Slicks. Oil pollution of the Mediterranean concerns the European Community of Nations (EC). Archimedes is an ongoing, EC sponsored, remote sensing field experiment aimed at refining sensors and techniques for routine, synoptic detection and evaluation of crude oil slicks on the sea surface. Evaluations include determining the size and thickness (i.e., volume) of the spill as well as information about the chemical composition of the slick. EC members actively participating in the project are Belgium, Denmark, France, Italy, The Netherlands, West Germany and the United Kingdom. Archimedes I was conducted off the Dutch coast (65 nm WNW of Zestienhoven Airport) in 1983. That project had difficulties due to the proximity of the study site to areas of coastal sediment transport and the type of oil used. These factors lead to abnormal slick dispersion. Consequently a follow-on study, Archimedes II, will be conducted. Archimedes II will occur from 1-8 October 1985. The experimental oil spill will be in a zone of clear water off the west coast of the island of Helgoland, some 40 nm north of Wilhelmshaven, Germany, in the North Sea. This is the same general area as the continuously manned German Research Platform, "Nordsee," which is operated by the German Ministry of Science and Technology. The staging area for the study will be the Nordholz Naval Airbase located 12 nm west of Cuxhaven, West Germany, which is at the mouth of the Elbe River. Desired meteorological conditions at the study site will be a wind force of 2-6 Beaufort with no rain or heavy fog. Developing the capability to detect oil slicks even in relatively heavy sea conditions is an important objective of this study. Three slicks, each formed using 20 cubic meters of oil, will be produced using three different types of oil. Two other spills will be made with monomolecular, film-forming surfactants (e.g., oleic alcohol) to simulate biogenic films. The ability to distinguish between natural slicks and those produced by crude oil spills is another important objective of this research and would be crucial to any routine monitoring program. An effort will be made to concentrate as many sensors as possible on the same aircraft to maximize the number of simultaneous, overlapping data sets. The main air carriers will be the Royal Dutch Air Force (RDAF) Cz-130, the German Aerospace Research Establishment (DFVLR) Dornier-228, and the French National Geography Institute (IGN) B-17. Four other aircraft will be available as secondary platforms or backups. Three separate overflights will be conducted at 1000 Z (day 1 in daylight), 1900 Z (day 1 in darkness) and 0800 Z (day 2 in daylight). Sea-truth sampling will be done by the German Hydrographic Institute (Hamburg). The German military synthetic aperture radar (SAR), flown during Archimedes I, will not be flown during this study. The management and logistics for Archimedes II is being handled by the EC Joint Research Center (JRC) at Ispra, Italy, with Dr. R. H. Gillot as Project Manager at ECJRC, 21020 Ispra (Varese), Italy; Telephone: 39-332-78911 (International). France, Germany, Italy, and the Netherlands are providing sensors. The following devices will be used:

- Microwave radiometers at various frequencies
- Infrared, ultraviolet, and multispectral scanners
- Side looking airborne radars (SLAR)
- Synthetic aperture radars (SAR)
- Laser induced radars (LIDAR)
- Photographic cameras

Phalanx Replenishment System. Designed to rapidly replenish the MK-15 Phalanx Close-In Weapon System (CIWS) ready magazine using the minimum time (less than 7 minutes) and exposing the least number of personnel to the elements and enemy fire. It is approximately 88 inches wide by 33 inches depth by 8.5 inches tall and mounts on top of the Phalanx electronics enclosure. Fully loaded the PDS contains 1505 rounds of 20-mm Phalanx ammunition and weighs approximately 1400 lbs. The empty weight is in the neighborhood of 500 lbs. The Phalanx Deckloader System comes fully supplied with all brackets, supports, and hardware for installation and once installed may be used to replenish either Block O or Block I Weapon System.

Goalkeeper. Goalkeeper is an autonomous and fully automatic weapon system for short-range defense of ships vs. high-speed missiles and aircraft. Dual frequency (I/K) band search and track radars are on one mount with

the 7-barrel GAU-8/A 30-mm Gatling gun (4200 SPM/1200 ready rounds). It provides continuous track of up to 30 targets, and can give maneuvering threat flight-path prediction to counter up to 60 targets. The Goalkeeper is a joint HSA and GE program with overall responsibility by Signaal. The Royal Netherlands Navy (RNLN) has ordered 16 systems. The UK's Royal Navy has ordered 15 systems – two for training, four for Type 22 Batch 3 Frigates (one/ship), and nine for three Invincible Class CVS (three/ship).

Shipboard Hanger Donors. MAFO had developed hanger doors of unique construction – a vertical, sliding unit of telescopic sections. The doors are both simpler and stronger than conventional installations and, equally important, they will use less weight and space. A high-precision product, these units can be supplied custom built or in standard sections up to a maximum size of 13 meters wide by 6 meters high. The bottom section is tailored to fit flush with the deck. Operation is the work of just one man. A push-button electric motor completely opens the door in less than a minute. The doors will still be operable in windforce 8. They will open and close in temperatures of 20°C with 10 cm of ice across the entire surface and with ship movements of 20 degrees list, 30 degrees roll and 7 degrees pitch. Hangar doors are in use with the following Navies:

Royal Netherlands Navy	6 *Van Speijk* Class frigates 10 *Kortenaer* Class frigates 2 replenishment ships 2 *Tromp* Class frigates
Royal Navy	1 Antarctic supply ship
French Navy	2 replenishment ships
Helenic Navy	2 standard-type frigates
Peruvian Navy	1 cruiser
Norwegian Coast Guard	3 patrol cutters
Danish Navy	4 frigates
Irish Navy	1 patrol vessel
Argentine Navy	4 *Meko* frigates.

Dutch Minehunters. In 1977 the RNLN selected the shipbuilding company of Van der Giessen-de-Noord (GNM), located in the vicinity of Rotterdam, to participate in the international tripartite project with France and Belgium and build the 15 new glass-fiber-reinforced polyester (GRP) mine countermeasures vessels (MCMV's). Production was started, and to date eight ships have been delivered to the RNLN. The ships are built in a line production fashion and one ship is completed every 21 weeks. GNM has gained a good reputation with the success of the Tripartite MCMV (Alkmaar class) and has recently moved into the export market with the sale of two MCMV's to Indonesia. They are competing for, and expect to win, the contract for two MCMV's to Egypt. To accommodate these sales the RNLN has agreed to delay the delivery of their remaining ships. Also GNM has designed a smaller CMVdesignated the CV325, a basic, more cost effective minehunting platform, which allows customers to install various systems to meet their specific requirements. The Tripartite MCMV is well known in Europe and has been the subject of many articles in international defense-related magazines. The most extensive coverage was a special supplement edition about GNM naval construction in *Naval Forces*, No. 1/1985, Vol. VI.

The construction of GRP ships was a revolutionary change for GNM, who had been primarily a builder of steel-hulled ships. To build the Tripartite MCMV, a completely new enclosed facility was constructed, a management team assembled, and a work force recruited and trained. To reduce the requirement for multiple purchases of high-cost tooling and facilities, the decision was made to build the ships in a production line where the ships moved from station to station to accomodate the work force and equipment. The production line of GNM has four undercover stations, the first two for GRP construction and the last two for fitting out. There is a fifth station for final testing and trials outside along the quay wall. The four stations are established so that each step takes 21 weeks. The learning curve has allowed GNM to make several modifications to the initial production process. It was discovered that the critical path was in the fitting-out stages vice the initial construction stage as was originally thought. As a result, many of the fitting-out items previously done in stations 3 and 4 are now accomplished in stations 1 and 2. The ships' hulls are constructed in station 1 using a mold of mild steel. The starboard side of the mold is rigidly mounted while the port side can be disassembled and moved to allow the hull to be transferred from station 1 to 2. The ships all move from station to station by means of inflatable air cushions rather than a fixed track system. This gives GNM flexibility in increasing production without additional capital expenditures by simply positioning the ships to use existing floor space, thereby increasing production from two to three ships per year to five ships.

Infrared Passive Detection and Tracking Systems from Hollandse Signaalapparaten. The improved effectiveness of ESM and ECM systems has resulted in the increased use of emission control (EMCON) with regard to radars aboard ship. Additionally, one of the major threats against today's surface ships is the high-speed, low-flying antiship missile. Most surveillance radars are not effective in detecting these missiles. Hollandse Signaalapparaten B.V. (SIGNAAL), located in Hengelo, has developed a number of passive infrared (IR) surveillance and tracking systems that can be used for either weapons control or target designation to other weapon directors. The IRSCAN (IR Scanner) is a passive surveillance system capable of detecting and tracking air and surface targets. The system operates in two spectral IR bands simultaneously: the 3- to 5-micrometer wavelength

emissions which emanate predominantly from very hot objects such as jet engine exhausts, and the 8- to 12-micrometer wavelength – the emissions from objects such as people, buildings, vehicles, and vegetation. Once IRSCAN has detected the target, it can be automatically designated to either active or passive tracking systems such as SIGNAAL's Lightweight Optronic Director (LIOD) or Lightweight Radar/Optronic Director (LIRON). It also can supply data for multisensor correlation by data handling systems. SIGNAAL also makes a land-based version for nonshipboard applications. LIOD is an unmanned director for automatic tracking of air and surface targets. It processes the optical contrasts of the target against its background as viewed by a television or infrared camera. Range information is provided by a laser range finder mounted on the director platform. Because of its modular design, LIOD can be used either as an autonomous or an integrated weapon control system dependent upon the equipment combination selected. The LIOD laser range finder is a hand- or computer-triggered laser range-measuring unit, beam divergency 1.2-1.5 mrad, measuring range 200-32,766 m, solid-state Neodymium-YAG laser transmitter with 1.06 micrometer wavelength and 20-nsec pulse length, maximum repetition frequency 10 Hz. LIROD 8/2 is the second generation of the SIGNAAL lightweight radar/optronic director. The system has been designed primarily as an autonomous target-tracking and observation system. LIROD 8/2 features multisensor logic: the most reliable signal, received either from optronics or radar, is selected automatically.

Protection Against Toxic Substances. Scientists at Prins Maurits Laboratory of the Netherlands Organization for Applied Scientific Research (TNO) are working on protection of humans against toxic substances, especially chemical warfare agents. They have developed nerve agent alarms, detection devices, and a mobile unit which can purify 3500 liters of water an hour from chemical-agent and radiactivity-contaminated water. They are leaders in the development and testing of individual and collective protection equipment. Risk assessment is accomplished by computer simulation of chemical attack and the effect of protective clothing.

9/15/88

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